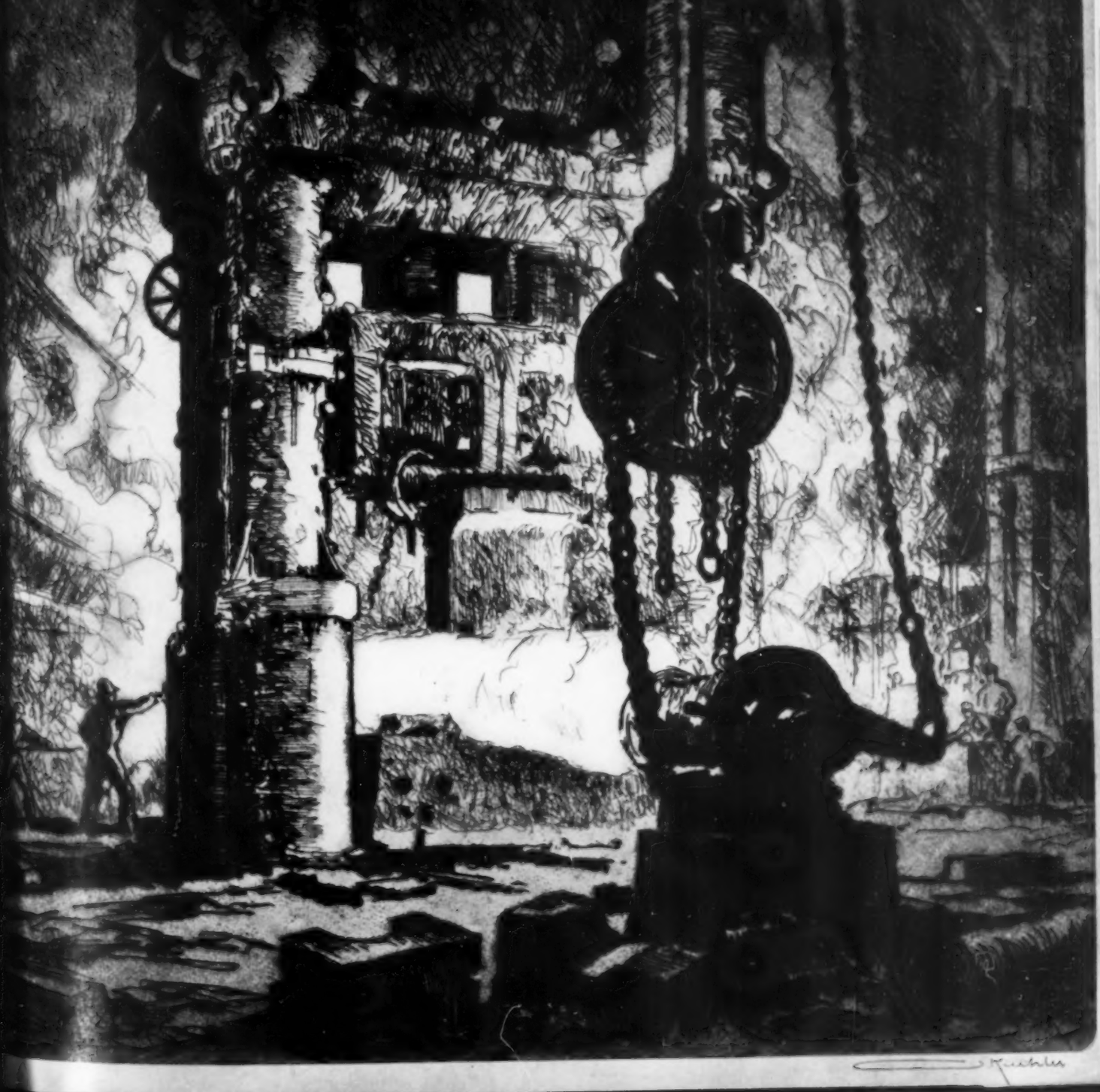
JUL 6 - 1936

JULY

METAL PROGRESS

1936



Already

MORE THAN A HUNDRED

SC DX GAS PRODUCERS

ARE USED IN INDUSTRY

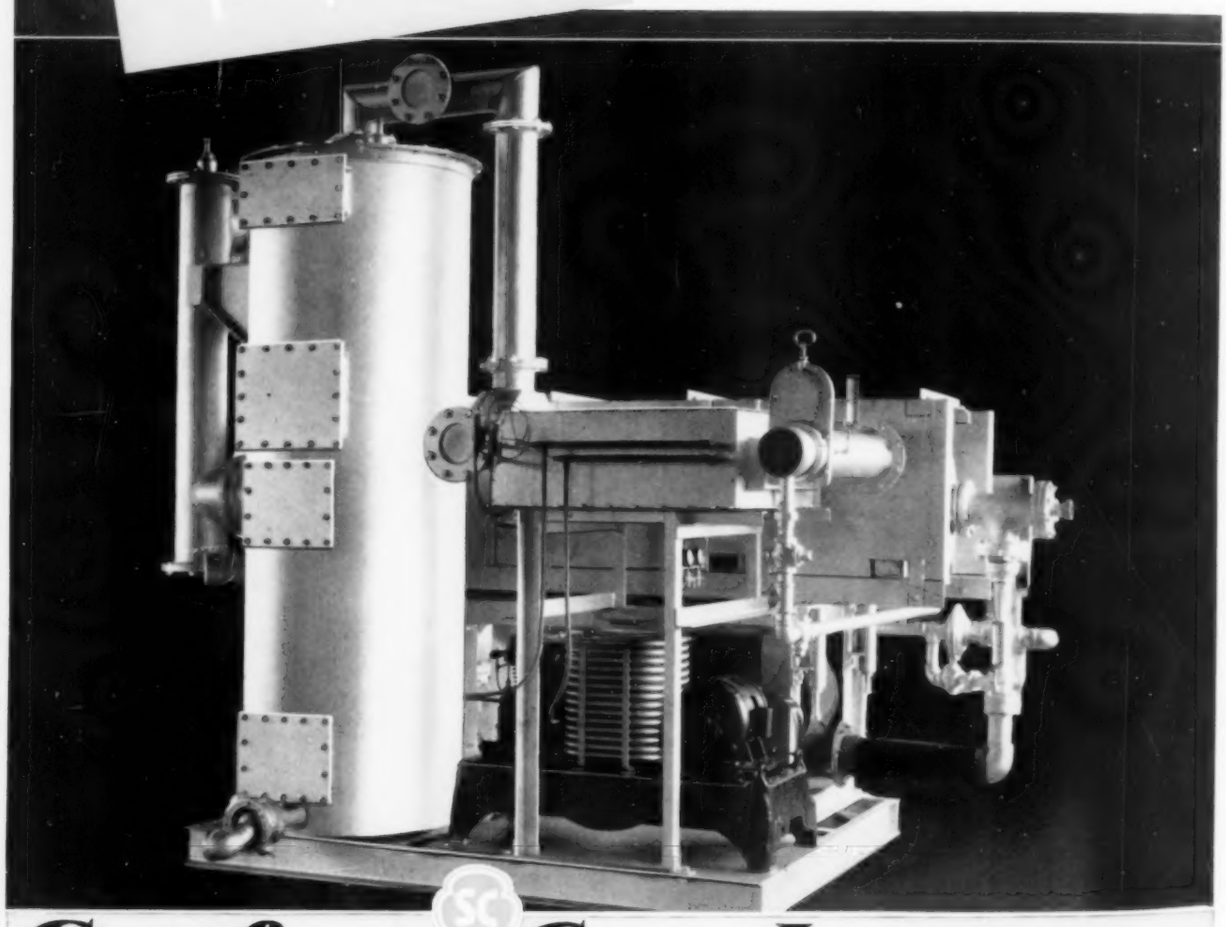
profitably

● DX Prepared Atmosphere Gas at a cost of *7c per thousand cubic feet has made practicable and economical the elimination or control of oxidation, scale, discoloration in the hardening, annealing and heating operations of both ferrous and non-ferrous metals. Since the development of Controlled Atmosphere Heat Treating and the SC DX Gas Preparation Unit, about three years ago, more than 100 of these units have been installed in the metal working industry, ranging in size from 300 to 15,000 cubic feet per hour in capacity.

DX Gas can be used throughout the entire heating and cooling cycle. It is *non-explosive, oxygen-free, of uniform composition, dehydrated and clean.* No expensive chemicals or materials have to be renewed. Costs are *one-third to one-sixth* of your present costs if you are using natural or city gas. And, most important, DX Gas produces a superior product and finish in bright annealing, in clean hardening, etc., eliminating the usual subsequent cleaning operations following heat treatment by old methods. Usually only the addition of a muffle or SC Radiant Heating Elements is necessary to use DX Gas in your present furnace equipment for controlled atmosphere heat treating.

Ask about its application to your production or call in an SC Engineer to survey your problem. It does not obligate you. SURFACE COMBUSTION CORPORATION . . . Toledo, Ohio.

*Based on 40c natural gas.



Surface Combustion

Toledo, Ohio » *Sales and Engineering Service in Principal Cities*

Builders of HARDENING, DRAWING, NORMALIZING, ANNEALING FURNACES
FOR CONTINUOUS OR BATCH OPERATION » » » ATMOSPHERE FURNACES

METAL PROGRESS

table of contents

FORGING A BIG TUBE .. .. Cover
An etching of a huge hydraulic press in action, reproduced by permission of the artist, Otto Kuhler

IMPROVED RAIL STEEL 33
The editor discusses the related problems of sound rails, flake-free forgings, heat treated rails and light weight rolling stock

THE SHIP QUEEN MARY 36
Information sent over by the English engineer and metallurgist, H. Grimshaw Martin, about the metals used in this new leviathan

HEAT TREATED RAILS 41
Observations on practices at Bethlehem Steel Co.'s mills for eliminating shatter cracks and for hardening the rails

HUBBING OF EMBOSSING DIES 46
G. R. Houghtaling tells how dies are made for embossing inexpensive personal jewelry in mass production—it's an art

POWDER METALLURGY 49
Words of caution from one who knows it's not easy

FLAKES IN FORGINGS 51
Two Italian research engineers confirm a recent hypothesis by soaking steel in hot hydrogen and thus causing flakes

DISCOVERERS OF THE CHEMICAL ELEMENTS 57

ABRASION RESISTANT STEEL 64
Advantages of a medium manganese steel for chutes and liners

A PICTORIAL STORY OF FORGING 67
The editor presents with considerable pride a new method of telling a technical story—many pictures and few words. Photos by Van Fisher; Text by Myron Weiss

CORRESPONDENCE FROM HERE AND ABROAD .. .. 59 to 63
Ultra Sound Waves for Locating Defects . . . . . by B. M. Suslov
Gage of Sheet Metal for Enameling . . . . . by Charles S. Pearce
Progress of Fusion Welding in France . . . . . by Albert Portevin
Selective Nitriding by Nickel Plating . . . . . by Federico Giolitti
Evaluation of Toughness of Tools . . . . . by Robert S. Rose

READER'S DIGEST OF CURRENT METALLURGICAL LITERATURE
Properties of Metals at Elevated Temperatures, C. L. Clark and A. E. White; Engineering Research Bulletin 27, University of Michigan, Mar., 1936 . . . 48
Metallic Wear, by H. W. Brownsdon 50
From Journal, British Institute of Metals, Vol. 58, 1936
Fatigue—Its Crystalline Destruction, By H. J. Gough and W. A. Wood . . . 91
From Proceedings of the Royal Society, Vol. 154, May 1, 1936
The Urbana Investigation of Rails, by H. F. Moore 96
From Report to A.R.E.A., July 1, 1936

HELPFUL LITERATURE .. .. 12 and 13
PERSONALS .. .. 92 and 94
ADVERTISING INDEX 106

Editor
Ernest E. Thum

Editorial Board
R. S. Archer
E. C. Bain
R. T. Bayless
W. H. Eisenman
H. H. Harris
Zay Jeffries
H. W. McQuaid

Published and copyrighted, 1936, by the American Society for Metals, 7016 Euclid Avenue, Cleveland, Ohio . . . . Issued monthly, subscription $5 a year, current copies 50c. . . . . Entered as second-class matter, Feb. 7, 1921, at the post office at Cleveland, Ohio, under the Act of March 3, 1870. . . . . American Society for Metals is not responsible for statements or opinions printed in this publication. . . . . Editorials are written by the editor and represent his views. . . . . He is also sponsor for unsigned and staff articles.

JULY, 1936 VOLUME 30 NUMBER 1

MODERN PROCEDURE IN ALLOY STEEL PRODUCTION

• A SERIES OF ADVERTISEMENTS BASED ON TIMKEN METHODS

NO. 1

Research

Research is the foundation of progress. In the modernly equipped research laboratories of The Timken Steel & Tube Company, organized thought and experiment are constantly carried on with the object of increasing the quality and application of Timken Alloy Steels to broaden their field of usefulness.

Out of Timken research in the past have come some of the most important developments in the alloy steel industry. Such developments as Timken Nickel-Moly Steel for the production of carburized parts; and grain size control now recognized by users of alloy steel as a standard specification.

In the course of their work Timken research technicians cooperate closely with all other departments. Thus the ramifications of Timken research extend into every phase of Timken quality control — chemical, metallurgical and production.

As a result of its recently enlarged facilities and the broadening of its scope, the efficiency and value of the Timken Research Department have been very definitely increased.

THE TIMKEN STEEL & TUBE COMPANY, CANTON, OHIO

District Offices or Representation in the following cities: Detroit Chicago New York Los Angeles Boston Philadelphia Houston Buffalo Rochester Syracuse Tulsa Cleveland Erie Dallas Kansas City St. Louis Cincinnati Huntington Pittsburgh *World's Largest Producer of Electric Furnace Steel*

TIMKEN ALLOY STEELS

ELECTRIC FURNACE AND OPEN HEARTH • ALL STANDARD AND SPECIAL ANALYSES

METAL PROGRESS

Vol. 30 July, 1936 No. 1

Improved Railroad Rails

An Editorial

ARTICLES on pages 41 and 96 concerning improved manufacturing methods for heavy rails find a welcome place in the same issue as the discussion of sound forgings by the Italian engineers I. Musatti and A. Reggiori (page 51). In truth the aim of rail makers is to produce metal free from internal "shatter cracks," a type of defect that is Siamese twin to "flakes" in forgings. It is particularly noteworthy that the technique recommended to avoid them in both instances is the same, namely to cool the metal slowly almost stone cold. The Europeans say the defects occur during cooling in the interval from 550 to 400° F. and specify furnace cooling of heavy forgings through that range; the Bethlehem engineers cool rails slowly in a covered box from below the critical to less than 400° F., and I. C. Mackie of Dominion Steel & Coal Corp. writes that he "cools slowly in a box, 120 at a time, for from 24 to 30 hr. down to a temperature within 100° F. of the surrounding atmosphere. This practice has been abundantly proven to be 100% preventative of shatter cracks."

It is apparent that we are getting closer and closer to the solution of two long standing and vexing problems — flakes in forgings and transverse fissures in rails. While one cannot accept without reservation the new hypothesis that flakes in forgings are caused by internal pressure of hydrogen suddenly released from solution slightly above room temperature, a great step in advance has been taken when we are able to produce flakes at will, and not wait until some of them happen along and ruin an expensive forging. Similarly, the riddle of transverse fissures, appearing sporadically in railroad rails, no one knew when, was well toward solution when H. F. Moore and his co-workers at University of Illinois found they could produce them in new rails containing shatter cracks (but not in sound rails, new or old) by merely rolling loaded car wheels back and forth, stressing the rails no higher than loads measured in the field under actual traffic. Sound rails, under larger stresses — above the fatigue limit — will break from a crack starting *at the surface* and gradually extending through the section, and not develop the dangerous defect known as a transverse fissure from a deep seated nucleus.

The problem of the *safe* rail, then, safe against unpredictable fracture, is the problem of sound metal. The article on page 41 of this issue shows how the commercial problem of controlled cooling has been solved in Europe, Canada and the United States. It is so convincing a story that railroads are gradually bringing themselves to pay the extra money required for this treatment. The Canadian National Railways, for instance, have specified this type of rail exclusively for several years.

It should be stated that some rail makers believe that a sound, safe rail is better made by normalizing than by merely slow cooling. John Brunner and A. D. Beers of Carnegie-Illinois Steel Corp., working on the theory that a coarse grained structure in the rail head predisposes sound rail to internal transverse fissures under traffic, recommend that the rails, after cooling below the critical but before reaching the "blue-

brittle range," be placed in a furnace and reheated until the entire section is uniformly and slightly above the critical, thus recrystallizing the metal into a fine grained structure. They are then run out for quiet cooling in air. (Ends are usually quenched in air blasts to harden them against wheel batter.)

Obviously, this process of grain refinement does not harden the rail but toughens it materially. In the standardized drop test, rails cooled on the hot bed will break on the first or second blow with 2 to 4% elongation, whereas the normalized rail will not break until the fifth or sixth blow with 9 to 16% elongation. Whether it will produce rails entirely immune to internal transverse fissures or whether slow subsequent cooling will be necessary depends on the accuracy of the theories underlying the two processes.

* * *

NONE OF THE ABOVE, however, solves the problem of a harder, stronger, more wear resistant rail. The trend for a century has been toward heavier wheel loads, not only heavier engines but heavier freight and passenger cars. Steel makers have attempted to keep pace with this trend by increasing the carbon in the steel rail, thus hardening it. This has long since reached the limit at practically eutectoid composition. Alloy steel has not made progress on account of its expense, except for the medium manganese rail, wherein the carbon is lowered to about 0.60% and added hardness given by 1.25 to 1.50% manganese. Well over a half-million tons of this are in track, principally in lines of the Lackawanna and New York Central railroads. Other analyses, such as the interesting 3% chromium steel rail containing only 0.25% carbon described by G. B. Waterhouse in METAL PROGRESS in April, 1934, have only been tried in comparatively limited tonnage.

It is realized at the outset that the high carbon steel in heavy rail is the approximate equivalent, chemically, of tool steels for sledges and all sorts of battering tools — consequently there are large possibilities for improvement of the standard rail, as rolled. It has been halted principally by the fact that prompt and effective heat treatment of the very large tonnages coming out of a modern rail mill would require an enormous auxiliary plant, and warrant a sizable increase in delivered price, which the purchasers have never been willing to pay. Rails have become a standardized product, procurable at only a few mills, and in this instance standardized practices and prices have prevented more rapid metallurgical development. Conditions are quite different in the production of splice bars, of which many proprietary designs are vigorously promoted. Nearly all of them are made of 0.50 to 0.60% carbon steel, punched and notched while the bar is still hot from the final pass, and immediately quenched in oil (not tempered).

A summary of the proposals for heat treating rail is given below. Such methods have never been given much encouragement by the railroads. There is, of course, another solution open and they apparently are taking to it more readily than buying hardened rail, either alloyed or heat treated. This is the construction of light weight rolling stock. Really light weight, high speed passenger trains are with us, and are bringing travelers back to the railroads. Wheel loads are greatly reduced by diesel-powered units constructed of aluminum or stainless steel.

It is also possible that freight cars have grown too big and heavy. Lighter cars and engines in more portable units will do much to compete with motor trucks handling most commodities. Since even the heaviest sections of untreated carbon steel rail — in fact all elements of the permanent way — are near their capacity for resistance under present axle loads from the enormous engines and coal cars now in operation, the best solution of the whole railroad problem may usher in much lighter cars and engines under which the present carbon steel, even rolled in smaller rail, will be quite safe.

* * *

THE METALLOGRAPHER may be interested in a fuller discussion of what has been done in the way of heat treating rails, and the resulting structures and properties.

Sandberg is probably the best-known name in connection with heat treated rails, for the so-called "sorbitized head" rails promoted by the Sandberg brothers have been made in large tonnage, especially for streetcar tracks. The process simply consists of running the hot rail direct from the last pass in the rolling mill to a station between a pair of perforated air pipes, and holding it there long enough for a multitude of air jets at moderate pressure to cool the head well below the critical range. The word "sorbite" is a misnomer, for what is done is merely to cool the hot steel rather more rapidly through the critical range than it would on an ordinary hot-bed, yet not fast enough to prevent the transformation of austenite to pearlite. Resulting microstructure is a somewhat finer pearlite on the running surface than in the rail cooled

more slowly on the hot-bed. The relationship between hardness or strength and the fineness of the pearlite in rail steel is very accurate, as has been shown by O. V. Greene.

The process developed by E. F. Kenney and Bethlehem Steel Co. is mentioned in the article on page 41, and the data indicates that the metal cools at such a rate that much of the austenite transforms at about 900° F. directly to finest pearlite. This mechanism is explained brilliantly by E. C. Bain and his associates. What martensite does form during the quench is immediately tempered, and the resultant structure is a mixture of finest pearlite and sorbite, and should be quite free from deep-seated stresses and incipient ruptures.

The Pennsylvania railroad some time ago laid a moderate number of rails which had been oil quenched or water quenched from 1550° F. and drawn at 875° F. Their tensile properties are similar to those described by E. W. Goodaire in METAL PROGRESS last March. The latter were oil quenched and drawn at 800° F. in vertical furnaces after machining into parts for frogs and crossings. In all of these quenched and tempered rails the elongation is increased about one-third and the reduction of area more than doubled; hardness ranges from 337 to 352 Brinell, an increase of 70 points over the rail as rolled and cooled on the hot-bed.

This simultaneous increase of hardness and ductility after quenching and tempering may seem impossible, but one should remember that the usual inverse relationship (hardness up, toughness down) is largely derived from comparisons between carbon or alloy steels in the quenched and tempered condition. This has an entirely different microstructure from as-rolled rail, which is essentially a fine pearlite, the result of moderately slow cooling through the critical, whereas the oil or water quench forms hard martensite in most of the structure and subsequent drawing tempers this to tough sorbite. In sorbite the precipitated carbides are in very fine rounded particles embedded in a continuous matrix of ferrite, and in pearlite the carbides are in parallel platelets, separated by thin films of ferrite. Therefore, the mechanical properties of sorbite, the quenched and tempered structure, cannot be compared directly with those of pearlite of the same chemical composition. As a matter of fact, the toughness of a truly sorbitic structure (quenched and tempered) is clearly superior to that of a pearlitic structure (slowly cooled) when equal in strength or hardness.

Latest Spectrographic Developments

IN RESPONSE to an invitation, as noted on page 35 of last month's METAL PROGRESS, the following letter has been received, which is gladly printed.

The modern Spectrograph, sold by the Braun Corporation of Los Angeles, was developed by Dr. M. F. Hasler and R. W. Lindhurst, formerly of the California Institute of Technology, at that Institution and their Applied Research Laboratory. My own contribution was the idea for the Projection Comparator which they have developed as standard equipment. With the co-operation of all the reputable local assayers they set a price of $6.00 for the complete Qualitative Spectrographic Analysis.

Using a grating instead of a prism, a 12½ inch film on a radius, means for a multiplicity of charges in carbon electrodes, and many minor mechanical improvements, enabled them to get much better resolution and far greater sensitiveness. Direct comparison of an unknown with a master film having an iron spectrum with markings of some 210 principal lines of 70 elements has changed hours of comparison to about 15 minutes with an increase of accuracy and decrease of limitations.

There is a good view of a considerable part of the spectrum with ample means for checking doubtful lines. Some 2230 Angstrom Units are projected on the screen to about 45 feet in length. Of all methods I know this one is least liable to error and results are regarded as final by all the reputable local assayers.

Most of our work comes from Pacific Coast and other assayers and mining engineers. Reports show percentages roughly as 0.001, 0.01, 0.1, 1.0 and 10.0% or between these figures.

I use the Spectrograph as a preliminary to all complete quantitative analysis, thus constantly checking results under varying conditions, for detecting minute amounts of impurities and then checking the quantity with the extremely accurate Polarograph, for testing composite samples for mining companies, determining minor associated minerals, complications, unsuspected values or for geological information. Assay buttons are tested for the Platinum group. Evaporated water residues are tested for poisonous elements or for general information. Country rocks or magmas of different periods are tested for differences and other possible information. Rare earths have been found in this county and hitherto unsuspected metals on the coast.

I use the Spectrograph in exposés of mythical values in alleged ores of tin, mercury and other metals. Governmental Agencies have made use of the Spectrograph both in my own office and elsewhere.

Even in medical work advances are made because of the rapidity and certainty of comparisons. You see at a glance instead of making tedious measurements with their possibility of error. There is an ever widening application.

(signed) JOHN HERMAN, D. Sc.

THE SHIP QUEEN MARY

uses much fine metal

PUBLISHED accounts of the new and record-breaking Cunard passenger ship Queen Mary each reflect the interest of the editor and his field of readers. The popular press is likely to emphasize size and make such comparisons as that Columbus' entire fleet could be put in the main dining-room. The business press argues whether the ship and its expected sister can regain the blue ribbon of the North Atlantic, and make any money. The technical and engineering press will concentrate on mechanics, construction and operation; appropriately enough the following will endeavor to give some idea of the 50,000 tons of metals used in hull and machinery.

Of course, the mere size of the ship is wonderful. Why is it necessary to build a 1004-ft., 80,733-ton monster to carry 2139 passengers when the Acquitania — a fast ship only 20 years in the same service — carries 3230 passengers and is only 902 ft. long and displaces 53,200 tons? The answer is that it takes three ships like the Acquitania to provide one weekly sailing in both directions, England to America, whereas the Queen Mary and a sister ship yet to be constructed — two of them — are capable of making a crossing every week.

This sailing schedule is the key to the answer of "Why so large?" Deducting the hours in port necessary to clean, refuel and revictual the ship, the required speed figures out at 28½ knots. The maximum should be even higher so the ship can spurt to gain time after fog or storm delays. The practical problem of getting the necessary propelling machinery for a minimum hull to carry it at 30 knots worked out to 200,000 hp. and a leviathan so large that the upper decks are unusually spacious, ample for dining-rooms, lounges, shops and corridors, and even generous-sized cabins (mostly outside) for the expected number of passengers.

The result is a spacious ship; one has the feeling of being in a well-appointed, modern hotel — not cramped, free to move about. Even the machinery rooms are not as tightly packed as in a Great Lakes steamer.

With the main dimensions fixed, innumerable experiments with models in a tank determined the exact shape of the hull. Autographic devices recorded the main data; moving pictures were also taken for additional information. Scale models of the completed ship with smoke coming out of funnels and air sucking down the ventilators were studied in a wind tunnel to make sure that the smoke would not swirl down and touch the ship anywhere. Propellers, which have given so much trouble in recent large ships, were most intently studied. Carefully made screws (1.60

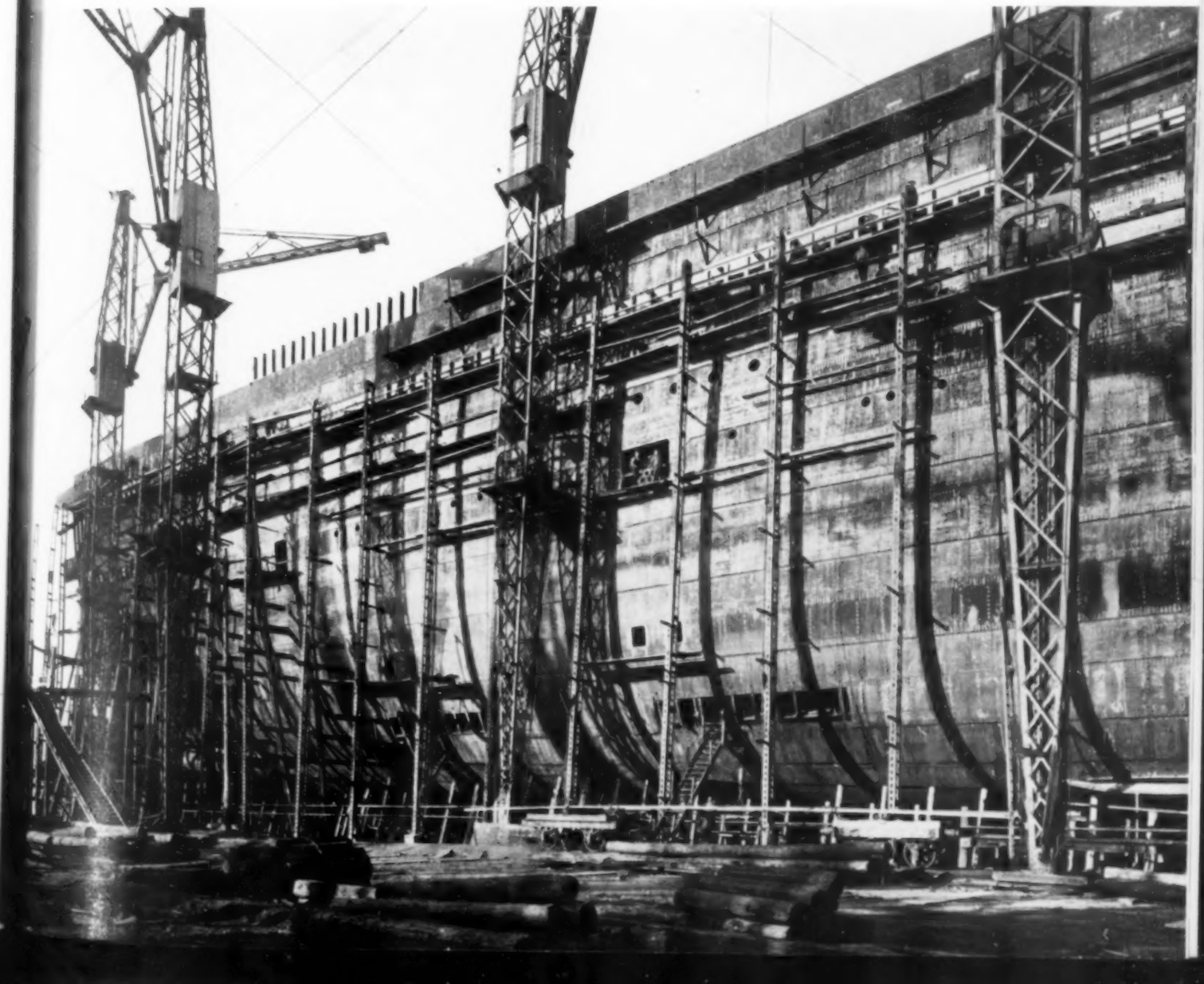
size) were first tested behind ship models in the tank, then others twice as large were run in open water, and finally screws 24 in. in diameter (1/10 size) were designed, constructed and subjected to about 1000 experiments. Propellers themselves are four-bladed; an appreciation of their size can be had from the view on page 38. They are four in number, of manganese bronze, cast in one piece weighing 50 tons rough, 35 tons finished. Being 20 ft. diameter, they are said to be the largest non-ferrous castings ever made, and cost about $35,000 each.

The hull of the ship — over 1000 ft. long, 118 ft. beam and 92½ ft. high to the topmost strength member — was so far beyond customary sizes that it was questionable whether the ordinary formula marine architects have been using to approximate the principal stresses should be extrapolated. The ordinary assumption is that the hull is a large beam and may ride midships the crest of a wave whose length is the length of the ship. Under these conditions a comparative figure for bending moment (found to be safe for ordinary ocean liners and freighters) is equal to the length times the load displacement divided by an empirical constant, usually 30. In order to find out something about this constant, careful computations were made; using the actual weights and their dispositions, it appeared that this constant for the Queen Mary should be reduced to 28.7, thus increasing the figured maximum stresses correspondingly.

When civil engineers design a record-breaking span for a bridge they can be expected to make use of high strength or alloy steel in main members. Conservative British naval architects made few such concessions to present-day metallurgy, placing their almost complete dependence on ordinary ship plate and shapes, getting extra strength from extra metal and its careful disposition rather than from stronger steel. For instance, the ship's bottom, 6 ft. deep, with shell plating 1.20 in. thick, forms the bottom chord of the huge beam which the hull is. It gets extra longitudinal strength from the inner walls of the oil bunkers which completely line both sides of

Even the Hull's Stern Dwarfs Everything

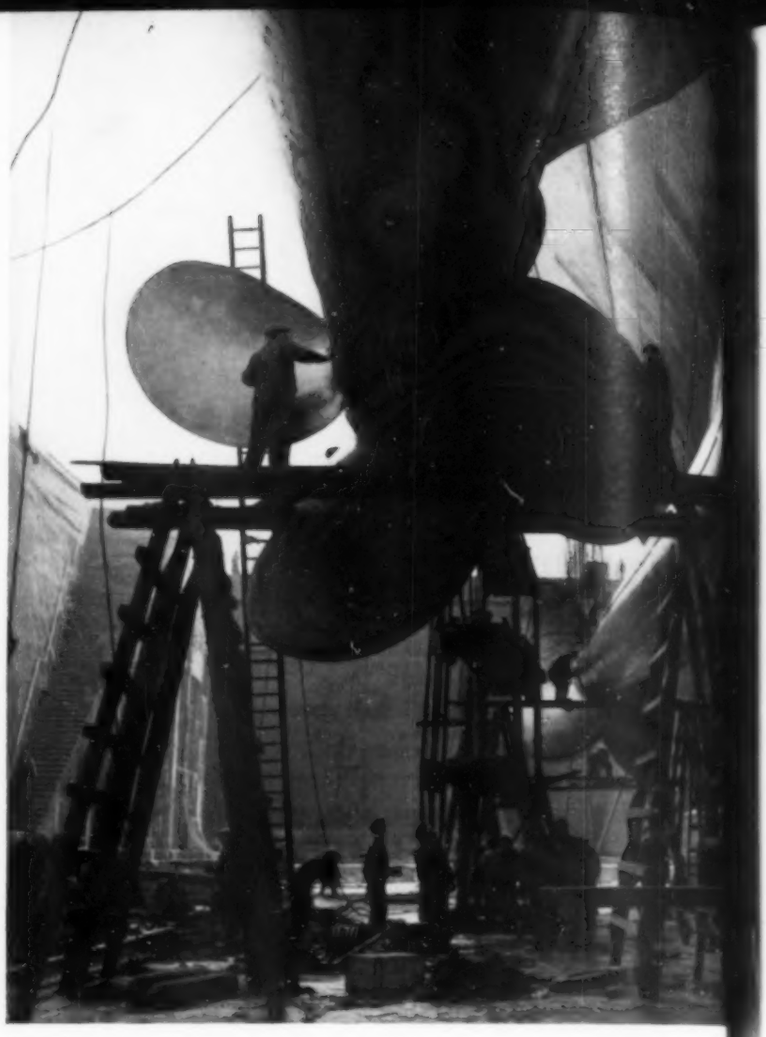
Photos by Stewart Ba



the ship. The promenade deck 92.5 ft. above is the top-most strength member, and is made of well-stiffened double plate a total of 1.26 in. thick. Of course, all the upper decks are strongly cross-braced together into a structural unit and trussed around the large openings required for funnels and public rooms, the whole group being in effect a cellular top chord for the hull, visualized as a huge beam.

Some 4000 tons of high elastic limit steel (a heat treated carbon steel developed by F. G. Martin with true elastic limit of 37,000 psi. on the average) was used in the upper part of the structure; Lloyds' regulations allow a reduction of 11% in thickness when this is used, but only part of this allowance was accepted.

Again looking at the hull as a beam, the webs are the side plating, 1.14 in. of steel, and longitudinal bulkheads. Transverse strength and shearing stresses are also taken care of by stiffness in all floors, crossframes, and intercostal fore-and-aft girders. All in all, the designers are quite confident the ship has ample structural strength for the heaviest weather on the North Atlantic.



50,000 Horsepower on Each of These Four-Bladed Bronze Screws Drives the Ship Forward

Practically all joints are riveted, there being about 10 million rivets. Machinery bases are welded to a certain extent; the only other major parts using notable amounts of welding are the davits and carriages for the life-boat launching mechanism. The plumbing and ventilating systems also utilized welding freely.

Steel castings at stem and stern are enormous. The stem casting runs up the prow and thence far back into the keel; it is 130 ft. long in five pieces bolted end to end. In cross-section it is a rounded V amply braced by diaphragms; wall thicknesses vary from 1½ to 4 in. The stern frame is in five sections weighing 190 tons. Outer shaft brackets (four sections) weigh 180 tons, two inner shaft brackets weigh 60 tons each, and the rudder stock 110 tons in two pieces. All of these are acid open-hearth steel cast from two 60-ton furnaces, and the sinkheads weighed in most instances almost as much as the completed part. Other difficult castings were the four stem tubes, 26 ft. long, 35 in. inside diameter, 4 in. wall. These were cast vertically with high sinkheads, and it was a problem to build cores that would stand the hydrostatic pressure yet crush under the contraction forces.

Obviously many important decisions cluster around the installation of a 200,000-hp. power plant, encased even in so generous a hull. Fortunately naval experience was available and has been largely followed. Water tube boilers are fired with oil and pre-heated air — another technologic improvement that has made the sweaty stoker, the "hairy ape" of literature, an extinct animal.

Each boiler has three water drums, one steam drum and one superheater drum. All are about 22 ft. long; the steam drum is 54 in. diameter with 2-in. wall, and the others somewhat smaller. These are enormous hollow forgings (each made from a pierced ingot in a press, as shown by the etching on the front cover of this magazine) machined inside and out and the ends closed in to oval manholes. Steel in the water drums has 67,500 psi. tensile strength, in the steam and superheater drums 80,000 psi.; its chemical composition has not been disclosed.

Seamless steel boiler tubes are straight, 1⅜ or 2 in. diameter; the superheater tubes are bent to hairpin and are 1⅛ in. cold drawn steel. Air heaters of the tubular heat interchanger type are

set in the flue above the boilers; their tubes are lap welded corrosion resistant steel.

Boilers deliver steam through seamless steel mains, unusually large, at 400 lb., superheated to 700° F., it being reduced to 350 lb. at the main turbine intakes and to 250 lb. for auxiliary prime movers and turbo-pumps. Each of the four propellers has its own 50,000-hp., 4-stage turbine, each stage driving a pinion meshing at one element of a 14-ft., double helical gear, keyed to the propeller shaft. Gears and pinions are of toughened 3% nickel steel, ground to 0.001 in. — no small task on a 20-ton gear blank!

Turbines Have Stainless Fittings

Turbine casings for high pressure and first intermediate pressure are of cast steel, the two lower stage casings of cast iron; all have partitions and nozzle plates of stainless steel, cast in. Rotor spindles, impulse wheels and reaction stage wheels are forgings with 75,000 psi. tensile strength. Each one of the 257,000 turbine blades has been tested and fitted by hand; all impulse blades are heat treated stainless steel forgings; reaction blades are low carbon stainless iron.

Propeller shafts each transmitting 50,000 hp. are hollow forgings 27½ in. diameter of high tensile steel; journal bearings are of cast iron lined with white metal (babbitt). A very elaborate thrust bearing is required of a type developed by ample marine experience. Thrust is taken from a forged collar on one section of the shaft, through white metal pads, ¾ in. thick, anchored to ten special hard iron segments. The opposite side of these segments pivots on a case hardened steel plug with rounded face, bearing against a spring steel disk set in the body of the thrust bearing. The entire drive of a single propeller is thus carried on only ten ball-to-plate contacts, whereas each thrust block is anchored to the ship's frame with 32 fitted bolts, 2½ in. diameter.

Including copper in 18,000 hp. in 528 motors installed here and there throughout the ship, enough lights for a city of 150,000 inhabitants, and 735 miles of copper cable and 4000 miles of light, phone and signal wire, there is about 3,000,000 lb. of copper, brass and bronze in this floating hotel.

Notable items are the four main condensers each with 14,000 seamless tubes of 70:30 copper-nickel alloy, 1¼-in. tube plates of rolled naval brass (62% copper, 37% zinc and 1% tin), and diaphragms and division plates of gun metal. Since the greatest care is used in maintaining the purity of the feed water system, the condensate reheaters and handling equipment are almost exclusively of brass in the cooler portions and copper when the temperature is between 115 and 370° F. Condensate pumps have casings of gun metal, spindles of stainless steel, and impellers of monel metal.

In order to minimize internal corrosion in the boilers, all contact between air and feed water is rigorously prevented, and oxygen is kept below 0.02 cc. per liter in the closed system by steam jet air ejectors on the condenser shells. Leaks of salt water from the cold side are guarded against by 16 continuous chemical analyzers connected to alarm bells and lights.

It is a matter of pride to the builders and even to the English nation that the ship is all British — practically all the raw materials, machinery and experienced personnel coming from within the Empire. It is to be expected, therefore, that the interior decorations will not be garish — the keynote is "modern, but not repellent." Wood, fabric, leather, linoleum, glass, have been largely used in decoration; 50 or more varieties of wood have been used in panelings and walls, so that the passenger, once inside, gets the distinct impression of an oaken ship.

Little Metal in Staterooms

A striking feature which is noticeable throughout all the stateroom accommodation is the almost complete absence of visible metalwork. Composition products have been employed for all door handles, coat-hooks and minor fittings which harmonize with the color scheme, are warm to the touch and remain clean indefinitely. All doors are flush with the walls, without moldings or beadings of any description, and the few exposed metal articles considered essential, such as ventilating louvers and plumbing fixtures, are of non-tarnishable steel. All alleyways are lined with a light, polished wood and the skirtings meet the floor with a specially rounded cove for cleanliness.

This general rule of little or no gleaming metal is modified in some of the public rooms. For instance, in the "Moderne Bar" the color scheme is steel, red and cream; in the cocktail lounge the walls are in wood, bronze, silvery stainless and aluminum sprayed material. Handrails and stair treads are generally stainless steel rather than brass. Terrazzo paneling in the two swimming pools and in many private baths is

A Short Piece of the Chain Cable, Electrically Forged From 4⅛-in. Bars of Open Hearth Steel, Proof Tested to 650,000 Lb. Each link is 24 x 15 in. and weighs over 200 lb. Three links, tested to destruction, break at about 1,500,000 lb.

attached by angle and T-bar sections made of stainless steel drawn over sectional material of bronze, thus being completely non-corrodible and highly decorative.

Stainless steel is most evident in the galleys (kitchens to land lubbers). All cabinets for hot foods are of stainless, the mirror-polished moldings and fittings contrasting well with dull polished panels and body work. Table tops and sinks are of stainless steel and monel. Ovens utilize high chromium-iron for linings; outside surfaces are white enamel trimmed with stainless steel. Altogether about 15 tons of stainless sheet and strip are utilized in this department of the ship alone.

Metal Decorations

Of course, some very beautiful metal work is utilized for architectural decorations. The pierced and carved bronze gates to all the restaurants represent various items of sea mythology. Bronze sconces and silver-bronze reflectors harmonize beautifully with the English oak paneling in the smoking-room. The usual number of bronze and aluminum objects of art are also placed correctly at vantage points — in fact, the interior decoration of the ship itself expresses the best efforts of a score of the leading artists in England. But take it all in all, from the riveted hull of mild steel to the upholstered furniture in the first-class cabins, the builders have avoided innovations for assurance of great substantiality and comfort. Only in unobtrusive apparatus — radio, navigating, ventilation, culinary — are the works of the recent inventor frankly utilized.

RAILS ARE IMPROVED

by heat treatment

by controlled cooling

WE FREQUENTLY HEAR that "the old-time rails were better than those now produced; they never broke and seldom wore out." This is an unjustifiable conclusion in view of the much more severe conditions that modern rails must meet.

Of course rails have increased in weight. Compare the 152-lb. Pennsylvania rail described by T. J. Skillman in METAL PROGRESS, Nov. 1931, or even the 131-lb. rail in common use on main line with the 100-lb. section which was the maximum of the former period. However, this increase in weight is more than offset by a 100% increase in static wheel loads, combined with higher speeds which raise the dynamic loads to measured values of twice that of the static loads. Consequently there is now a far greater pressure of the wheel on the rail and this is confined to an area of contact only slightly larger than under the old conditions.

The result has been an increase not only in wear but in the number of rail failures, despite the best efforts of the steel-mill metallurgist. From the blast furnace through the rail mill there has been an increasing application of scientific knowledge for controlling the many chemical, metallurgical, and thermal factors involved in the manufacture of railroad rails. It remains axiomatic that a good rail can be made only from good steel. Metal and slag analyses, mold preparation and use, design and operation of furnaces, temperature control of rolling, and chemical and metallographic checks — all have contributed to the steady advance. All of this care in preparing good steel and rolling it into a rail should not be vitiated by neglect in the subsequent treatment, thereby lessening its value as a safe and serviceable product for the use of our railroads.

In the early days rails were frequently discarded because the head mashed or crushed. The steel was too soft, too low in carbon. Many are the tales told about clashes between the old-time iron master and the early steel-mill chemists, but nevertheless chemical control rapidly cured mashed heads, except on secondary lines where relaying was delayed.

Then came the "split head." This type of failure was mainly confined to rails from the top of the ingot. They were troublesome, but as they gradually developed in plain sight of track walkers, the rails were generally removed before they became dangerous. As these split heads increased under the growing severity of traffic, railroads objected strenuously, but they were annoyed rather than alarmed.

They really became alarmed by a wreck on the Lehigh Valley railroad in 1911. It was traced to a rail, broken through an internal transverse rupture which had gradually developed during service and without any external indications. This marked a new phenomenon in rail failures which is now commonly known as the transverse fissure.

Typical Transverse Fissure Discovered in Worn Rail (Above) and Shattered Condition of Head (Below). Photos courtesy of H. F. Moore. After fissure had been located electrically, the rail was partly sawed through and head broken. Other end of rail was then sawed longitudinally through center of head, surface polished and etched with 50% HCl. Reproduced about two-thirds actual size

Internal Transverse Fissures

In recent years these transverse fissures, more through their insidiousness than through their frequency, have been the cause of more concern to the rail maker, rail user, and steel metallurgist than all other types of rail failures. What is their cause? What is their cure?

The last word has not yet been said as to the cause, but much has been done in the way of a cure. The ideas and practices of the pioneering investigators the Sandbergs, Gerhardt, and Mackie have been confirmed in essentials by recent scientific studies at the University of Illinois, under the auspices of the Association of American Railroads and the Rail Manufacturers' Technical Committee.

This important work has been summarized in November's METAL PROGRESS. (See also page 96.) Rails were subjected to wheel loads simulating service conditions yet under laboratory control, and this developed transverse fissures in those rails that were susceptible thereto. Non-susceptible rails developed fatigue cracks starting *from* the surface, and therefore visible to an inspector, rather than *within* the head, and therefore invisible. Quoting from the official report: "Tests have yielded fairly convincing evidence that fissures in rails usually originated at shatter cracks which formed in the rails during the process of manufacture."

Nearly ten years ago, Messrs. Sandberg of London, England, internationally known rail engineers, pointed out that shatter cracks, which occur occasionally in rails as rolled, may act as the foci from which transverse fissures gradually develop within the heads of rails during service. They believed that "one of the chief causes" of shatter cracks is stresses caused by "a substantial difference of temperature during cooling between the outside metal and the interior metal, more particularly of the big mass in the head of the rail."

Hence they believed that if shatter cracks could be prevented the transverse fissure problem would be solved. Before the end of 1928 they had developed a method of controlled cooling at the Cargo Fleet Iron & Steel Works at Middlesbrough, England, which effectively prevented the occurrence of shatter cracks. In the succeeding year they introduced this method into the United States, where, after experimentation by the Bethlehem Steel Co. on the higher carbon American rail, the process was adopted on a commercial scale. More recently the method has also been used by Inland Steel Co. and Colorado Fuel and Iron Co.

R. B. Gerhardt of the Bethlehem Steel Co. and I. C. Mackie of the Dominion Steel & Coal Corp. of Sydney, Nova Scotia, likewise diagnosed shatter cracks as the principal cause for transverse fissures and found the cure in the controlled cooling of rails. At the present time the last-mentioned company is subjecting its entire output of rails to controlled cooling. In the above-mentioned tests

at Urbana, none of the controlled cooled rails had shatter cracks or manifested internal fissures when subjected to fatigue tests.

It is known that only a small percentage of the rails cooled in the usual way on the hot-bed contain shatter cracks. But their occurrence is insidious. Shatter cracks are sometimes found in rails produced from a particular ingot of a heat and absent from other ingots of the same heat. A limited portion of a rail is sometimes found to contain a few shatter cracks while the rest of the rail is entirely free from them. Therefore, no real assurance of freedom from shatter cracks can be had unless *all* rails are subjected to the controlled cooling operation. Without vaccination the majority of human beings might not have smallpox, yet universal vaccination is the only sound prophylaxis.

After five years of experimentation the commercial process as applied at the mills of the Bethlehem Steel Co. may be outlined as follows:

Rails are cooled on the hot bed in the usual manner until the temperature has dropped as low as 1000° F. but not less than 932° F. As illustrated in the adjoining photograph, they are then placed in boxes or tanks in sufficient number to insure a slow and gradual drop in temperature. After being loaded, the boxes are covered; the rails are protected from cool currents of air. Moreover the boxes are under cover and protected from snow and rain. The rails remain until they have dropped below 400° F.

There has been some difference in opinion as to the ranges of temperature wherein rails are most susceptible to the formation of shatter cracks during cooling. The Sandbergs, for example, inclined to the belief that the tendency to shatter crack was greatest between 932° and 650° F., while Gerhardt and Mackie had the view that it was greatest below 650° F. Both the Sandbergs and Gerhardt agreed, however, that in practice it is important to start at a sufficiently elevated temperature to allow a substantial margin of safety. Mackie, in describing an application of his process which is "100% effective in eliminating all traces of shatter cracks," stated that the rails are allowed to cool normally on the hot-bed until visible redness in a dim light disappears, and then are placed under the cooling hood as promptly as practicable.

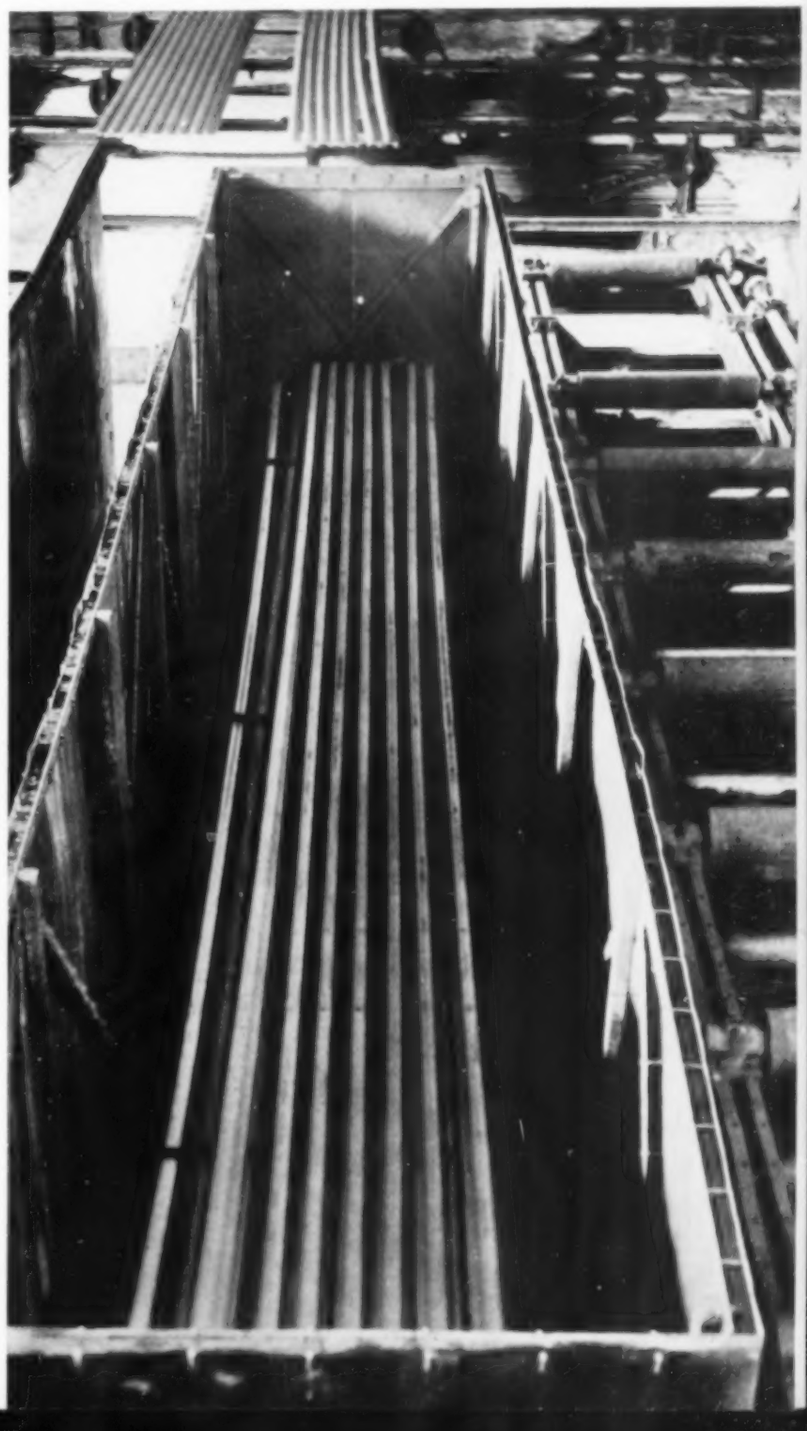
Controlled cooling also reduces residual stresses substantially; thereby the rails show considerably higher results in bend tests than rails cooled on the hot-bed in the ordinary way. The ductility is better. All these results are obtained without appreciably affecting the hardness of the rail, either by Brinell tests or by measurements of wear under traffic.

Production of such rails in Europe has reached approximately 1,000,000 tons. In the United States and Canada it now aggregates about 385,000 tons. Thermal processes of one sort or another are now in commercial use in practically all American rail mills.

Quenched and Tempered Rails

When the demand from the railroads for rails capable of greater and greater loads first appeared, metallurgists naturally began to con-

Shattered Condition in Head Can Be Prevented by Slow Cooling From Below Recalescence to Near Room Temperature. Photo shows cooling box at Bethlehem Steel Co.



sider the feasibility of quenching and tempering rails, and thus producing the well-known effects of greatly increased hardness and strength. About 30 years ago various methods of heat treating rails began to appear in the technical journals and patents. It was soon discovered, however, that a rail offers special obstacles. Its peculiar cross-section with its unequal distribution of metal, its great length, the great mass of metal, particularly in the head, and the high carbon content, all contribute to the difficulty of effective, yet safe, quenching. For years attempts were made to solve the problem with but indifferent success.

Nevertheless the need for rails of higher physical characteristics was becoming increasingly apparent. The present trend is decidedly in the direction of higher speeds in train service. Under the higher speeds on tracks today, the dynamic wheel load sometimes exceeds 100,000 lb. At times nearly all of the enormous axle load on a pair of wheels is concentrated on a single wheel. The entire braking effect at high speed may be applied on a small area of contact between one wheel and rail, amounting to only 0.5 sq.in. Under these concentrated loads the surface metal of the rail tends to flow, a tendency opposed by the underlying metal, thereby resulting in great tensile stresses in the interior of even the soundest rail head.

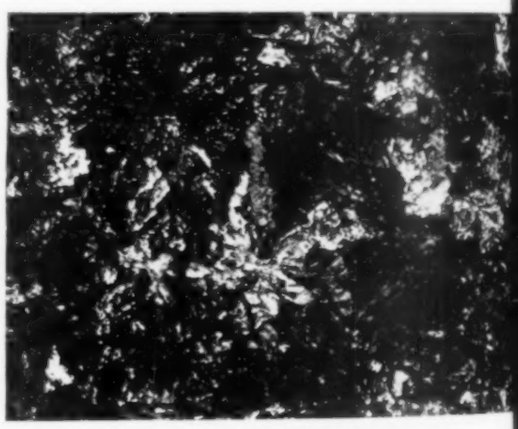
Heat treatment of rails effectively meets this present and prospectively greater need for high physical characteristics. A practical method was developed by Edward F. Kenney, of the Bethlehem Steel Co., after a period of experimentation lasting some 20 years, whereby the damaging internal strains that had caused internal checking are entirely avoided. His process is described in U.S. reissue patent No. 17,240, and its practical embodiment as practiced by Bethlehem Steel Co. involves quenching the rail while cooling from mill heat, discontinuing the quench at a definite temperature, promptly effecting equalization at an elevated temperature, and finally subjecting the rail to controlled cooling in a box.

[Editor's Note: As studied and described by the Bureau of Standards the rail from the last pass is held until the edge of the base becomes magnetic, then the rail is quenched head down in water at 60 to 100° F. for about 30 sec. and immediately run into a tempering furnace at about 900° F. Studies at the Bureau of Standards indicate that just before quenching the edge of the base is about 1200° F., the surface of the head is 1360° F., and the center of the head is 1500° F. (Ac_{1-3} is about 1350° F. for this material. Ar_{1-3} begins at about 1280°). In the brief quench the very surface layer cools almost instantly to 215° F., but the center of the head drops at about 8° F. per sec. This rate at the center is maintained after the rail is removed from the bath, for then the cold surface is reheated from the internal heat and the whole rail approaches uniformity 60 sec. later at about 900° F. (the temperature of the tempering furnace) and is held there for about 2 hr. See page 34 for a discussion of the expected microstructure.]

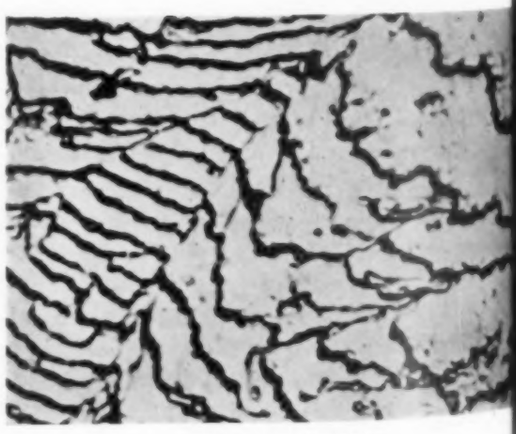
High Elastic Limit

Tests on nine heats of 130-lb. R.E. section rails are summarized in the table opposite. Part of the rails from each heat were cooled on the hot-bed, part were given the Kenney heat treatment. The figures, as well as the photomicrographs, plainly indicate their superiority for resisting the stresses induced by high train

Microstructure of Quenched and Tempered Rail Appears Merely as a Finer Grained Aggregate When Viewed Under Low Power but at 2500 Diameters the Rail Cooled on the Hot-Bed Is Shown to Consist of Pearlite, Whereas the Heat Treated Rail Contains Much Sorbite, Tougher and Harder



Untreated, 100 ×



Untreated, 2500 ×

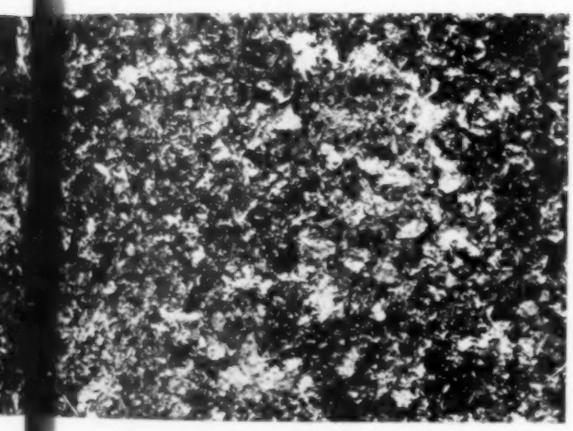
speeds. Kenney's aim was to produce rails in which the elastic limit was sufficiently high to greatly minimize or entirely prevent the plastic flow of the outer metal of the rail head due to the concentrated wheel loads. The figures indicate a 50% increase in elastic limit due to heat treatment. Not only does the greater elastic limit inhibit the tendency to plastic flow of the outer metal of the rail head but the high elastic limit of the inner metal enables the steel to resist effectively the tendency of the outer metal to flow.

Moreover, the heat treated rail has a far greater life than untreated rail, due to its increased resistance to wear. According to recent reports from five railroads the average wear in either high or low rail, when heat treated, was only 54.8% that of the untreated rail.

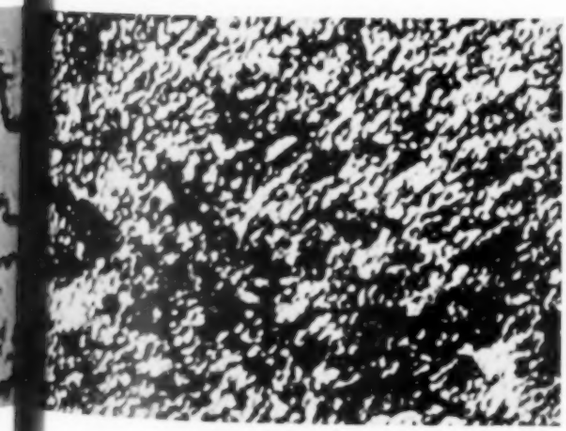
A special method of heat treating rails involving the application of vaporized water ("Scotch Mist") to the rail head, followed by a controlled cooling, has been developed by Messrs. Sandberg of England. This process is now used by most of the rail making plants in Europe, and more than 100,000 tons of rails have been so made. While this process has not been used in the U.S., its possibilities must not be overlooked.

Tests on Eight Heats, 130-Lb. Rail
Average Analysis: Carbon 0.74%, Manganese 0.72%

	Heat Treated			Not Heat Treated		
	High	Low	Average	High	Low	Average
Tensile strength	185,000	170,000	177,900	151,000	133,800	140,600
Elastic limit	131,000	123,700	126,700	89,000	77,800	83,300
Elongation in 2in.	10.5	7.5	8.5	10.5	6.5	8.7
Reduction of area	20.5	9.5	13.6	14.8	9.0	12.0
Brinell hardness of head	375	347	363	311	269	298
Permanent set, first blow in drop test	0.66	0.50	0.54	0.93	0.80	0.86
Izod impact			7.0			2.0



Heat Treated, 100 ×



Heat Treated, 2500 ×

The Problem of End Batter

Under modern service conditions the joint is one of the weakest elements of the railway track. Long before rails are worn out by the abrasive action of the wheels, the joints have usually become loosened by wear on the contact surface between the heads of the rails and the tops of the splice bars. When the wear has become too great, rails are taken out of track, the ends cut off to remove badly worn parts, new holes drilled, and new joint bars installed on the shorter length rails. This relatively short life of the rail ends and bars is due in most part to the impact of the wheels in passing over the joints, especially where battering has formed a depression in the smooth running surface.

Battered ends have been rebuilt by depositing new metal from welding rod or electrode, without removing the rail from track, and then grinding the deposit to an even surface. It is cheaper and safer to prevent or minimize this battering by hardening the ends of the rails than to attempt to correct it after it has occurred. Several methods of hardening rail ends are being used at the present time.

One method is applied to new rails, immediately after laying in the track, where the running surface of two abutting ends is brought to the correct temperature by an oxy-acetylene torch and then quenched by means of a measured quantity of water. The hardened spot is then reheated to draw the temper. *(Continued on p. 102)*

THE HUBBING OF DIES

for embossing jewelry parts

By G. R. Houghtaling
Development Dept.
Hickok Mfg. Co.
Rochester, N. Y.

HAND-MADE JEWELRY of artistic merit commands a high price, exclusive of the value of any gems it may contain, because the patience and skill of the artisan who made it deserves generous recompense. Similarly it is found by the manufacturers of such mass production items of personal consumption as belt buckles and tie pins that a large portion of the cost lies in the preparation, by hand, of the embossing dies. Jewelry embossing in stainless steel or bronze or the more precious metals is done cold, and it requires tremendous pressures to duplicate a finely cut design. Hence the life of the dies is relatively short and the question of economical replacement is important.

A similar problem is met in the drop forging industry when the number of duplicate parts runs into the millions. For relatively short runs the die sinker cuts out the shape, intaglio, into upper and lower die blocks — as so excellently shown in the photographs on page 70 of this issue. When such a die is worn beyond allowable limits the top must be machined off, down to the bottom of the impression and an entirely new one cut. The only alternative is to make a die type or hub, which is a positive copy of the desired part, and force this hub into a block of steel, thus creating the desired impression or intaglio copy. This die block is then hardened and mounted in a hammer ready for forging. This process of die typing (or hubbing, as we would call it) as utilized by Ford Motor Co., was described in detail in an excellent and practical article by R. H. McCarroll in METAL PROGRESS, July, 1932, wherein he notes that such a master type or hub is good for the production of 200 to 400 forging dies.

A similar use of hubs is favored by the Hickok Mfg. Co. for the manufacture of jewelry dies. A hub is in reality a master or duplicate of the article to be embossed. Since all the work, both die making and jewelry embossing, is done cold no problem arises as to shrinkage allowances, but a more serious one arises because of the reluctant plastic flow of the cold metal under pressure. Hubs, being always made of steel, require the services of a steel engraver of artistic ability and long experience — the prototype of the die sinker in the forging industry.

Making the Hub

In brief, it is very often found best to spend the greater effort in making a hub, and from it make any number of embossing dies, replacing the latter as they wear or break under the intense pressure of use, than it is to sink an intaglio die.

The first step in making hubs is to select a suitable grade of tool steel. It must have the following requirements: Harden with a very hard surface, have great resistance to compression, and still have toughness and some resiliency. It must also gain these requirements without sacrifice in size changes when hardened. We have found the following analysis to meet all of these requirements in the average run of work: Carbon 0.65 to 0.75%, manganese 0.50 to 0.60%, nickel 1.50 to 1.75%, chromium 1.50 to 2.00%, molybdenum 0.25, vanadium 0.25%.

The hub is first machined in the customary way by machine tools to the point where hand work becomes necessary. This hand work of finishing is most exacting. Experienced hub cutters or steel engravers have hundreds of delicate chisels, punches by the dozen, riffle files, various shaped scrapers and intensely sharp gravers which are called upon to shape and form the steel hub to an exact and artistic representation of the article to be produced by embossing.

Plastic flow of metal must be kept in mind during the design and cutting of these hubs, for the creation of the embossing die (as later to be explained) and the embossing of the jewelry parts cause metal to form or flow cold, from a plain metal blank or slug into an intricate shape.

Draft or taper must also be considered, as no part of an embossing die may contain an undercut which would cause the blanks to stick in the die. There are also many other things to guard against, such as sharp corners and extremely deep projections. One of the secrets of efficient hubs is to produce smooth and true lines, and this calls for the skillful use of the multitude of various-shaped punches mentioned above. Raised and sunken lines or portions may be cut from the steel, but the actual finished surface must be burnished smooth by driving these lines with a smooth tapered punch. Thus the finished hub is as smooth as possible; they are, in fact, usually oil stoned and polished after they are hardened.

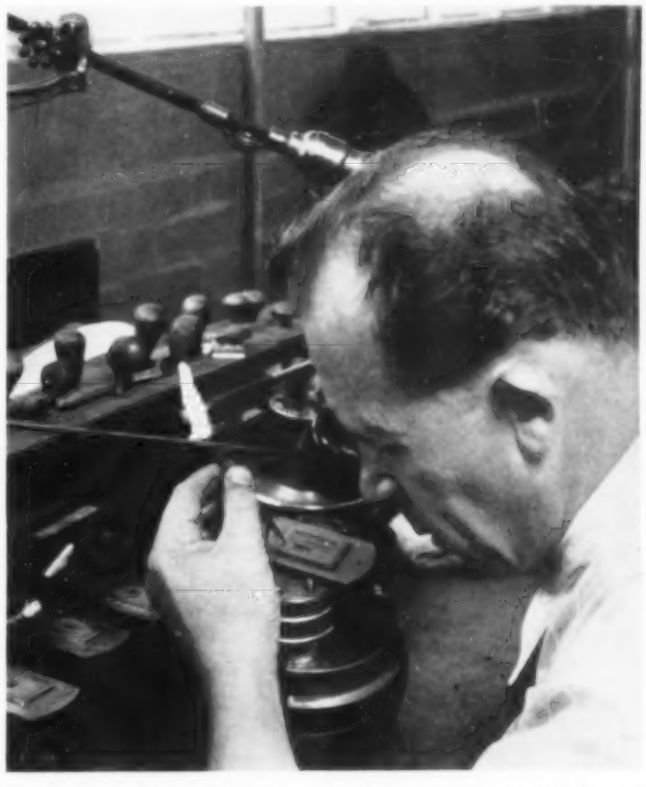
All the above cutting is naturally done on an annealed block of the nickel-chromium-molybdenum-vanadium steel. Hardening is the next operation. We heat the hub in a protected atmosphere, taking about 1½ hr. per in. for the smallest sections, starting the heat at not over 800° F. and continuing to about 1550° F. Hubs are quenched in oil and when cold are cleaned and tempered to between 350 and 400° F. for 2 hr. for each inch of section.

A die block is now prepared by machining any decarburizd surface from a forged block or bar of annealed steel. By experience we have found one best suitable for our work in coining presses; it has an analysis of carbon 0.60 to 0.70%, manganese 0.60 to 0.70%, nickel 1.25 to 1.75%, and chromium 0.65 to 0.85%.

Hubbing the Die

An important point is that the die block should be large enough in cross-section to resist bulging during hubbing. As the hub is forced into the die block the volume of hub must be displaced in some direction. Sometimes cavities are cut in the bottom of die blocks to take care of this displacement; again, auxiliary reinforcements are used to avoid bulging and splitting of blocks during hubbing.

Prior to hubbing the upper surface of the die block is surface ground, polished and buffed to a mirror-like surface. The hub is next placed against the polished die block and by slow pressure forced into it. There are numerous difficulties encountered; each differently shaped hub presents its own problem. Very often the die must

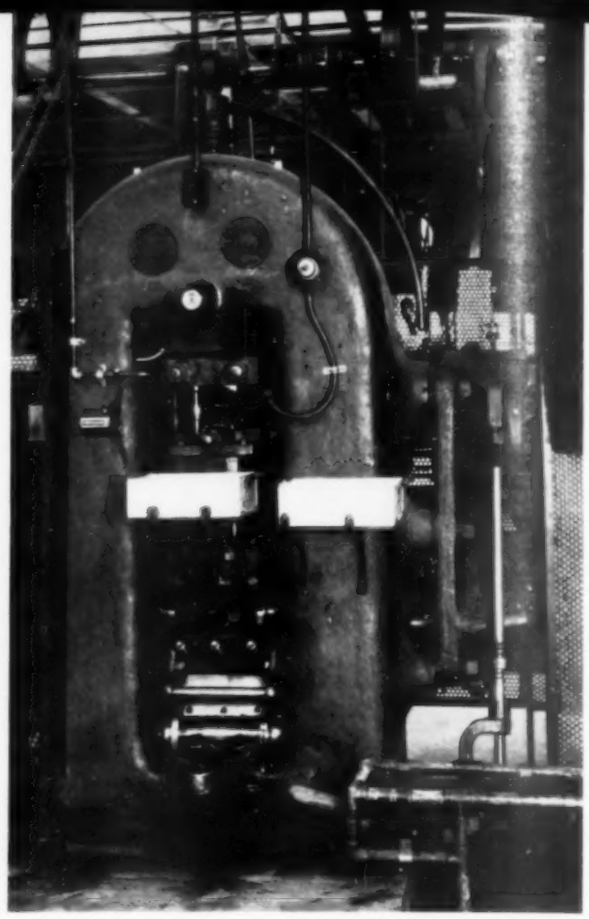


Embossing Dies Are Made by Pressing a Finished and Hardened Hub (a Finely Finished Replica of the Required Part) Into a Block of Alloy Steel. Hub making is the job of an expert artisan — really an example of steel engraving.

be hubbed in successive steps interspersed with an anneal — the surface, of course, carefully protected from oxidation or decarburization. When every minute detail of die has been forced into the hub, the external dimensions of the die block are finish machined to size. The pressure required for hubbing varies with the section and area of the hub; a safe average is 200 tons per sq.in.

Hubbed embossing dies should be fully and thoroughly annealed before hardening. For hardening the die is heated in a protective atmosphere for 1½ hr. per in. of the smallest section, starting at 800° F. and reaching the proper temperature between 1475 and 1550° F. depending upon carbon content. The steel is then quenched in oil and, when cool, cleaned and tempered between 375 and 550° F. Shallow dies should be tempered to about 375° F.; deep impressions having greater displacements of metal are tempered at a higher heat, namely up to 550° F.

Most jewelry parts are made of the various brasses, bronzes, nickel-silver, sterling silver and gold alloys, and a surface hardness of 70 to 75 scleroscope meets most requirements. We have occasionally made dies for bakelite articles and die castings in much the same manner as outlined above for embossing dies, namely using a modeled or engraved hub. Carburized low carbon steel is usually sufficient for dies for condensation products such as bakelite. They present some interesting problems because of the comparatively large displacement of cold metal which occurs when the hub is pressed into the die.



A 400-Ton Coining Press, an Example of Several in Use by Hickok Mfg. Co.

METALS AT ELEVATED TEMPERATURES

By C. L. Clark and A. E. White

Condensed from University of Michigan, Engineering Research Bulletin

IF A MATERIAL is to render satisfactory service at elevated temperatures, it must have a suitable combination of creep strength, tensile properties, and impact resistance. It must also possess stability of structure and, under the given operating conditions, must be able to resist corrosion and oxidation to the desired degree.

Metals at elevated temperatures possess both elastic and plastic properties though the plastic properties under certain conditions are the predominating ones. At these temperatures an elastic deformation occurs upon the application of a load below the apparent elastic or proportional limit, but if the temperature is sufficiently high this deformation is not independent of time, as was the case at room temperature, but increases as the time of application of load is extended. This increase in elongation with time under a constant stress is now commonly known as "creep."

The conception of creep which appears to the writers to be most in harmony with observed behavior follows: At elevated temperatures at or below the equi-cohesive temperature, which is the lowest temperature of recrystallization, the deformation or creep resulting from the application of stress over a given period is a running balance between the yielding of the material and the strain hardening caused by such yielding. At or below this range the strain hardening tendencies should predominate and continuous creep will not occur. In fact, the yielding of steel at room temperature when the proportional limit is exceeded is in reality a creep phenomenon, but unless the stress is sufficiently great, the deformation soon stops as a result of the marked rate of strain hardening.

At temperatures **above** the equi-cohesive temperature, however, the recrystallization rate exceeds the strain hardening rate *(Continued on page 194)*

POWDER METALLURGY

a warning

a promise

By Gregory J. Comstock
Assistant Manager of
Research and Development
Handy & Harman
Bridgeport, Conn.

IT IS PROBABLE that no new development of recent years has had a more stimulating effect on the imagination of those interested in metals than has the working of metal powders. Indeed, "powder metallurgy" is at present a term to conjure with.

It is easy to see why this is so.

The startling attributes of a few of the first products of this type of manufacture have publicized the possibilities it affords for departing from the more usual standardized procedures and products. The metals tungsten, molybdenum and tantalum — hard metallurgical nuts to crack — have yielded, although not too gracefully, to manipulation in powder form. Uniformly porous bearing material, hard cutting conglomerates, sintered compositions of non-alloying components have been produced from powders and have displayed such striking and unusual physical characteristics as to assure them a definite place in the industrial scheme.

These products were not born without travail, however. They were perfected, without exception, as the result of patient, arduous, protracted and often desperately disappointing endeavor, involving the expenditure of large sums of money. The statements that "Knowledge after the event is always easy," and that "Problems once solved present no difficulties" may be appropriately applied to comments one reads and hears about the comparatively simple procedures which have been developed for the current production. This apparent simplicity of practice has naturally enough encouraged easy speculation as to the general application of the powder process to many fields of manufacture and the development of a large number of new materials which also possess radically different and commercially desirable properties.

To the imaginative uninitiated, who has seen powders pressed and sintered in the current production methods, such a general application and development presents no great difficulty, either from a production or sales standpoint.

To those who have been more closely associated with the development of these processes and who are familiar with the countless unexpected obstacles which have arisen to check their progress, such a program of general application wears a different aspect. While they doubtless have even more confidence in the ultimate use and value of the powder process than their less directly informed associates, their enthusiasm is tempered by the knowledge that judging from the past, each new application must be attended by a large amount of pioneering endeavor and

that the principles and laws which govern the manipulation of the powders themselves are as yet extremely fragmentary.

We might, therefore, be expected to advance the warning that the application of this new and interesting principle of metal fabrication should be approached with a knowledge that it is not an easy road to travel. While it is not as yet rutted by the passage of a great deal of traffic, it is still, like an early western wagon trail, far from straight, laboriously detouring around unremoved obstacles, passing through marshes of unknown principles, and at times disappearing entirely, making it necessary to blaze a new way if the desired objective is to be reached eventually.

Approached with a true knowledge of the circumstances and difficulties which are attendant to work in this field, the future may be regarded as affording unusual promise.

Probable Developments

The application of hard cemented carbides, for example, has left a great, and as yet unfilled performance differential between tool steels and these materials. It seems quite likely that the casting process does not afford as logical a means of developing intermediate compositions to fill the gap between high speed and carbide tools as does the sintering of powdered ferrous compositions, highly alloyed by dispersion during that operation and subsequent heat treatment. Another example: The investigation and production of sintered ductile metal powders suitable for special electrical and magnetic purposes is being continued with considerable success as to its commercial application, based upon improved properties and results.

General knowledge with regard to this new art is slowly being accumulated. The day is gradually approaching when those molded metal products will be available which were so lightheartedly promised by those who have discounted somewhat the time required for this laborious accretion.

It would seem that the future promise of this new art may be appraised on the basis that, given an opportunity to demonstrate its possibilities without misrepresentation by over-optimistic understatements of the difficulties which are incident to it, it will open up new fields of considerable fertility and will afford other new and valuable processes and products through intelligent application — as developed by lots of good hard work!

METALLIC WEAR

By H. W. Brownsdon

Condensed from Journal, Institute of Metals

MEASUREMENT of wear between two metals can be brought about by causing the periphery of a moving wheel of one metal to come in frictional contact with a flat sample of another metal under known conditions. The dimension of the oval impression made on the flat sample may then be taken as a measure of wear, much in the same way as the dimension of the impression of a ball or pyramid is taken as a measure of hardness.

The conditions of simplicity of apparatus, coupled with accuracy of measurement and the obtaining of quick results, are met by a machine where a 1-in. wheel of hardened steel (diamond penetrator 775), 0.10 in. thick, with periphery rounded to 0.05 in. radius, is turned at 500 r.p.m. in a massive spindle. Pressed against it by lever arm and hanging weight is a table to which is firmly fixed a small flat plate of the metal to be tested (in these experiments of copper or copper alloys). The surface finish on both wheel and sample was that given by "00" emery paper, the wheel being polished after each test. All the tests were carried out under conditions of flooded lubrication and at room temperature.

The author's interest in this subject arose from a desire to study die-fouling when drawing hollow brass products. Experimenting in the plant was inconvenient; with the aid of this machine much information on the causes and prevention of die-fouling was obtained. The adhesion of metal to the surface of the steel die is akin to seizing in a bearing, and the effect of load, speed, lubrication, temperature, nature of the non-ferrous metal and that of the steel of the die, as well as surface smoothness of the die, all play some part in the phenomenon.

A delicate method for detecting fouling of the wheel is to run a series of 15-min. tests without cleaning the wheel. If the wheel is fouling, the length of the impression increases with each test. Using a light mineral oil as lubricant, the zinc-containing alloys, brass, and nickel-silver produced the most fouling or seizing on the wheel, the aluminum bronzes fouled the wheel slightly, while no fouling was visible in the case of copper, tin bronze and cupro-nickel.

A soap solution is frequently used to serve both as a lubricant and coolant in drawing dies, therefore a comparison was made between the wear obtained with oil and with a soap solution. While copper, aluminum bronze, and cupro-nickel gave much less wear with the mineral oil, the brasses and nickel silver showed more. Two main points of interest emerge from a consideration of these results: (1)

(Continued on page 100)

FLAKES IN FORGINGS

caused by hydrogen

By I. Musatti and A. Reggiori
Research Department
Ernesto Breda Machine Co.
Milan, Italy

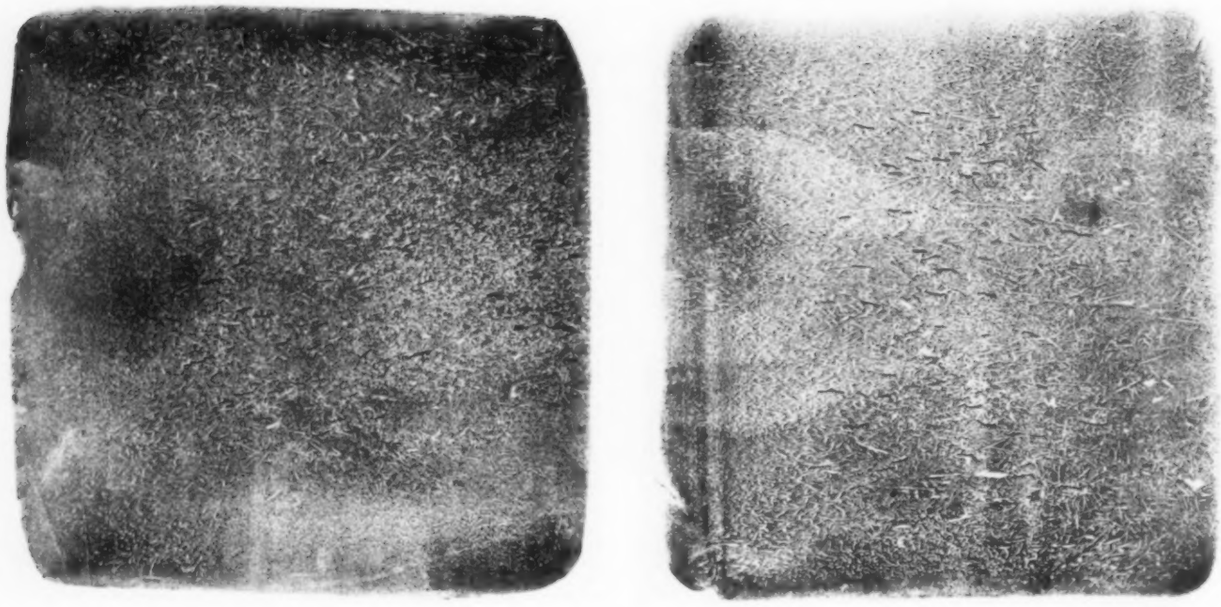
INTERNAL cracks often found in special steels deformed by hot rolling and forging are known by the name of flakes. The name comes from the appearance of the fractures of the affected pieces; flakes appear as roughly round areas with a crystalline grain which, especially in heat treated material, is distinctly different from the surroundings. The cracks are often under strong compression so that it is very difficult to find them on machined pieces; they are easily discovered by etching, however.

While the technological methods suitable to avoid flakes, or at least to lessen their likelihood, have been known for some time, their origins have only been brought to light quite lately. The first researchers ascribed them to the presence of inclusions, or to the existence of oxidized zones abounding in submicroscopic inclusions, or to gross defects existing previously in the ingots. After having noticed some correlation between flakes and dendritic segregation, others have brought forward the hypothesis that they are caused by internal tensions due to volume changes occurring in cores and boundaries respectively of the dendrites during cooling, as these changes take place at different temperatures in consequence of this segregation. Other investigators attribute them to the presence of strong internal stresses arising during cooling.

In checking these hypotheses, our first aim was to make sure if some relation existed between cracks and non-metallic inclusions. Many samples were examined, particularly some that abounded in non-metallic inclusions. Long alignments of silicate particles containing sulphides were found to be in relation with flakes in a few cases only. Therefore, while the inclusions present at or alongside the flakes may have considerable practical importance, because they can prevent the welding of same on subsequent forging and rolling, they cannot be the important first cause. This conclusion has also been reached by other competent investigators.

Next, in considering the supposed interrelation between flakes and segregation, a distinction should be made between "great segregation" or liquation in large ingots and that dendritic segregation which is inherent in the solidification of steel. The

A paper, somewhat abridged in translation, presented before the International Congress of Mining, Metallurgy and Economic Geology held in Paris last year, and reproduced by permission of the Congress



An Ingot, Split Longitudinally, Rolled Into 6-In. Blooms. Photos about half size. Note that flakes appearing in etched cross-sections do not favor an edge, where ingot segregation still resides

early opinion that the flakes come from defects existing in the ingot, such as piping cavities frequently found along the axis, is untenable, for their position, shape and surface appearance undoubtedly show an origin in the stage of working immediately before final cooling, or in the cooling itself. The hypothesis that a connection exists between flakes and segregated regions must be discarded since flakes are generally found in an intermediate zone between the axis and the periphery. Furthermore, the results of the following experiment give a direct confirmation of this statement:

A 16-in. ingot was split longitudinally and each part rolled to 6-in. blooms, which were allowed to cool in the air. Both abounded in deep-seated flakes, without any relation with the position of the more segregated part of the original ingot, now located near one of the sides. This fact is clearly illustrated by the macrographs reproduced half-size above.

A certain relation between flakes and dendritic segregation has been observed in many cases. Some experimenters deny this relation, and others say it is the fundamental cause. We believe that this correlation does not exist; if it is seen in some cases, it can be attributed to chance. As a matter of fact, flakes often follow the general direction of the dendritic markings on etched surfaces, but just as often they do not. Two photomicrographs are reproduced on the opposite page from many which show this fact.

Until quite recently information about the relation between flakes and cooling contained nothing more than observations on the *speed* of cooling. Recently extensive experiments by Houdremont, Korschan and their associates at the Krupp works in Essen, Germany, have shown that flakes form in a narrow interval of temperature, namely 400 to 600° F. (see *Stahl und Eisen*, 1935, p. 297 and 321 and METAL PROGRESS, July and September, 1935). Similar tests carried out by us on nickel-chromium-molybdenum steel have confirmed these results. As a matter of fact, the temperature of formation of the flakes in this steel has been found to be less than 535° F., although its exact temperature has not been established. The chemical composition of the many heats of steel studied comes within the following limits: Carbon 0.30 to 0.40%, manganese 0.40 to 0.60%, silicon 0.30% ±, nickel 2.7 to 3.2%, chromium 0.6 to 0.8%, and molybdenum 0.30 to 0.40%.

As Houdremont and Korschan pointed out, not one of the previous theories is sufficient to explain all the phenomena connected with the appearance and elimination of flakes. We have found, for instance, that while 8-in. blooms cooled in the air immediately after rolling abounded in flakes, blooms of the same heat cooled very slowly to 70° F. were free from flakes — even when the latter were reheated to 1850° F. and then cooled in the air under the same conditions as the flaky blooms. No flakes appeared in the flake-free blooms even when such heating and

cooling is repeated several times. Microscopic researches did not bring to light appreciable structural differences.

We also attempted to verify the hypothesis, as stated by B. M. Suslov in METAL PROGRESS for May, 1935, that segregated regions transformed at widely different temperatures and thus caused overpowering internal stresses. Experiments on 6-in. blooms of the Ni-Cr-Mo steel were therefore performed as follows:

(a) Immediately after rolling two blooms were cooled in the air to room temperature.

(b) Two blooms were cooled in the air to 535° F. (that is, too high for any residual austenite in the segregated zones to turn into martensite) and then slowly reheated to 1100° F., kept at this temperature for 2 hr. so that all austenite could transform and temper, and then cooled in the air.

(c) The same as *b*, except that the blooms were cooled from 1100° F. to 575° F. in the furnace, and then in the air.

(d) Other blooms were put in the furnace to cool slowly immediately after rolling was finished.

Only those blooms *d* that were cooled slowly *down to room temperature* were found to be free from flakes; all the others were affected.

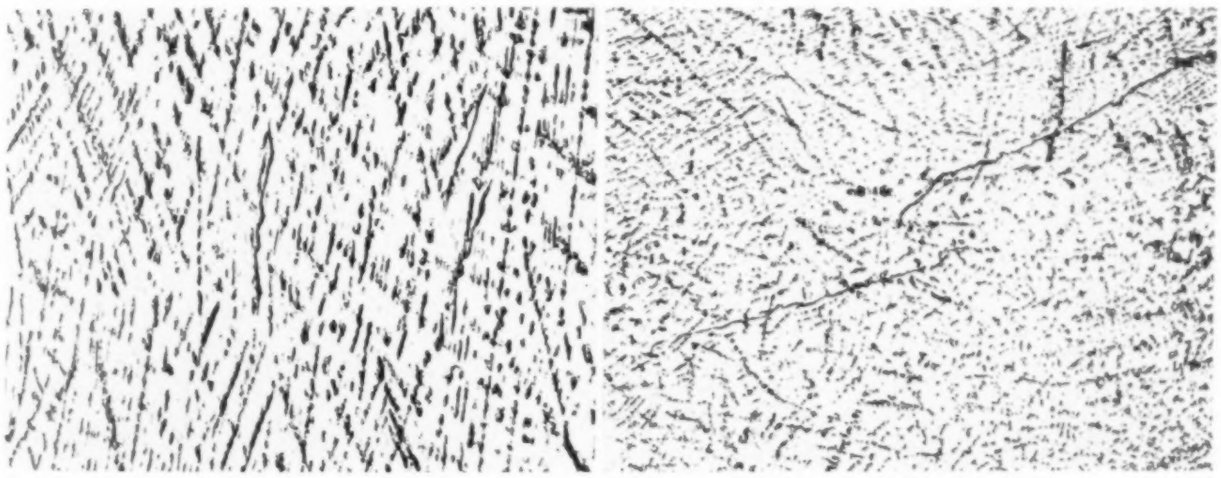
Seeing that the temperature of flake formation was less than 535° F., it does not seem very likely that they can be attributed to heat stresses. The time-temperature curves we took on the surface and in the middle of these blooms cooled in the air differed by only 25 to 35° F. — too small to form cracks.

Recently, German experimenters have come to the conclusion that flakes can be attributed to hydrogen present in the material. The mechanism seems to be very simple, since the solubility of hydrogen in iron becomes less with falling temperature. The free gas causes very high pressures, which in certain conditions can overcome the material's resistance and cause cracks in it. For the purpose of direct proof, Bennek, Schenck and Müller introduced hydrogen in the molten metal and then, to keep a sufficient quantity in solution, they used small ingot molds of special shape, as well as other devices. This gas can also be introduced into solid steel by prolonged heating in an atmosphere of hydrogen. By following this idea we succeeded in producing flakes in steels of different compositions that were completely free from them.

In the first experiment a 2-in. round bar of chromium-nickel-molybdenum steel was heated to 2100° F. for 7 hr. in a current of hydrogen, after which it was cooled in calm air. An end broken from it did not show any flakes. The rest of the bar was treated in the same way for another 7 hr. and another part detached and examined; it was also found to be free from flakes. After a third heating of another 7 hr., the bar was found to be affected with flakes as shown in the left-hand photographs on page 54.

The test was repeated with a larger bar of the same steel. When heated for 28 hr. in four periods of 7 hr. each, following each other, and cooled in the air after each heating, this bar was found to abound in flakes. Some fractures of this piece are shown in the same figure.

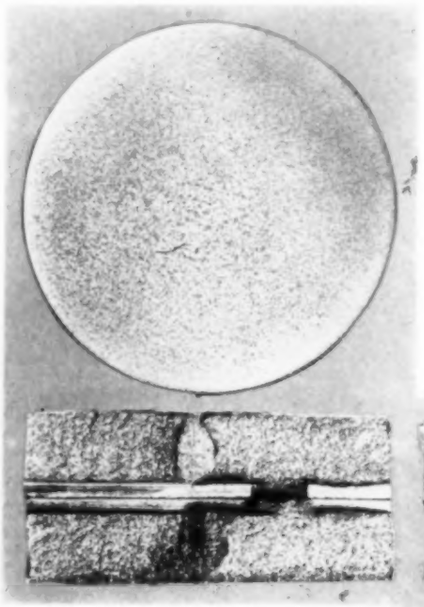
While flakes were not found in the first ex-



Dendrites in Flaky Steel, Etched With Oberhoffer's Reagent and Magnified 10 Diam. In one sample the cracks appear to follow dendritic segregation; in the other they do not

periment after 7 hr. in hot hydrogen, some flakes were found in later tests even after heating for 7 hr. This gives rise to the idea that repetition of the heating does nothing else but increase the number of the flakes until they reach such a quantity as to be found nearly everywhere.

It may moreover be thought that a rather long time is required for the hydrogen to reach the deepest parts of the piece, and the deepest strata enriched with hydrogen are the most suitable to give flakes, because it should be easier for the gas to diffuse from the more superficial strata before it can build up pressure sufficient to crack the piece. These considerations also explain the noted fact that flakes—except in extremely quick coolings that delay diffusion and elimination of the hydrogen—form in the more or less deep-seated zones.

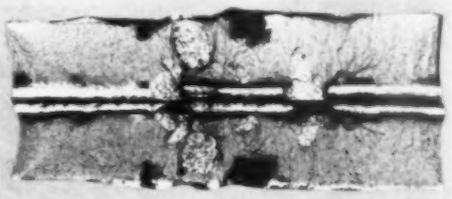


2-In. Bar Heated 21 Hr.

It is interesting to point out that the material used in these experiments came from 6-in. blooms containing flakes which completely disappeared in rolling them to 2-in. billets cooled in air. Round bars forged from these billets were also entirely free from flakes. Therefore flakes are re-introduced into the steel by the action of hydrogen. Contrary to what happens with the hydrogen, heatings in nitrogen at 2100° F. (which we have repeated to a total of 50 hr.) caused no flakes.

Similar experiments were carried out on 2½ and 3-in. cylinders of high grade carbon steel (0.40% carbon), a nickel-chromium steel with 0.30% carbon, 2.5% nickel and 0.85% chromium, as well as another nickel-chromium-molybdenum steel of the same general analysis as quoted at the outset. Three cylinders were heated at the same time in a current of hydrogen, namely, one of each of the steels, so that the experimental conditions could be strictly comparable. Finally each cylinder was heat treated to refine the grain and make the flakes more evident. Disks about ⅜ in. thick were then cut for pickling and for cross breaking.

After annealing in a current of hydrogen at 2100° F. for 7 hr., followed by quenching in water, flakes appeared in all three steels, but in different ways and to different extents. As shown in the upper macrographs page 55, they do not often exceed 0.10 in. diameter in the carbon steel, but they are rather numerous. They become larger and very numerous indeed in the nickel-chromium steel; they also tend to localize in an intermediate stratum several millimeters below the surface. The phenomenon, already serious, becomes more so in the nickel-chromium-molybdenum steel; here, as a matter of fact, it has literally disintegrated the piece except for a sleeve of sound metal. None of the large cracks went to the surface of the piece, except one on a base of the cylinder.

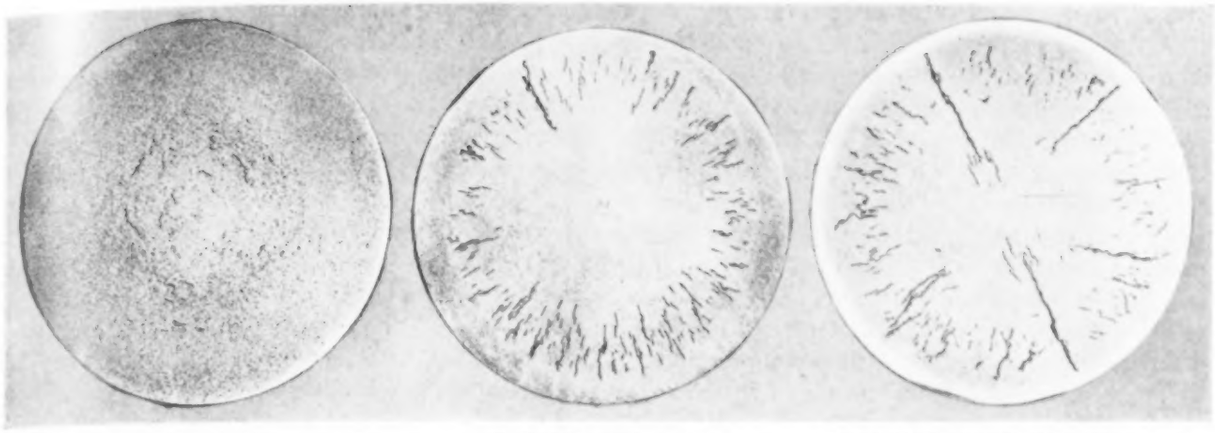


2-In. Bars of Nickel-Chromium-Molybdenum Steel, Originally Sound, Rendered Flaky by Heating in Hydrogen at 2100° F. and Cooling in Air. One disk at right was heat treated to refine grain and emphasize coarsely crystalline appearance at flakes

2¾-In. Bar Heated 28 Hr.

After annealing in a current of nitrogen at 2100° F. for 7 hr. followed by quenching in water, neither superficial nor internal cracks were found in any of the three samples examined. The fractures made during testing were found to be normal and fine grained.

Annealing in a current of hydrogen at 2100° F. for 5 hr. followed by partial cool-



Carbon Steel *Nickel-Chromium Steel* *Nickel-Chromium-Molybdenum Steel*

Various Susceptibility of High Grade Steels to Flake Formation After 7 Hr. in Hydrogen at 2100° F., Followed by Water Quench

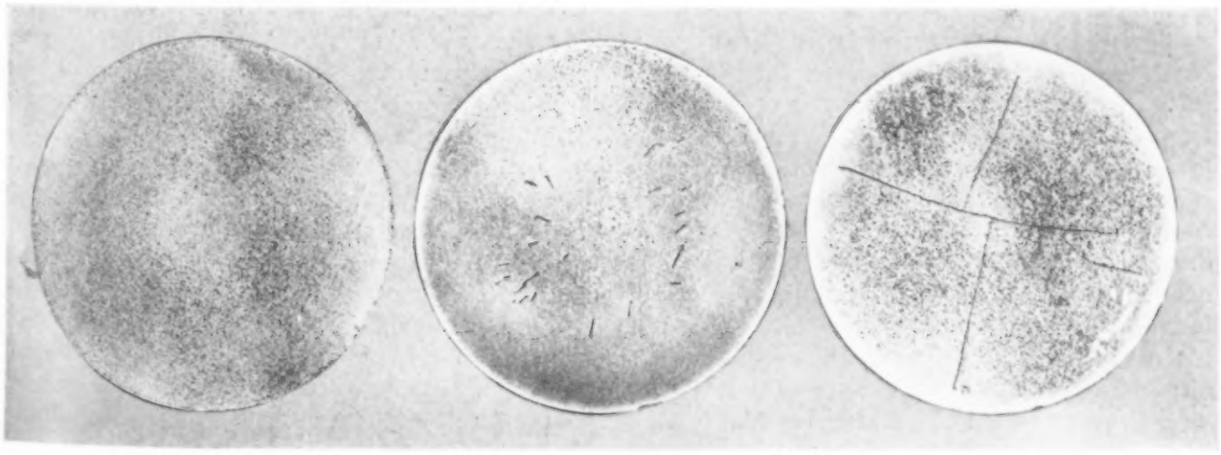
ing in the furnace in a current of nitrogen, taking 75 min. to reach 1300° F., and then quenching in water caused numerous flakes in all the three steels studied. This treatment was to relieve the heat stresses connected with extra-high quenching, and to see if in this temperature interval the diffusion of hydrogen from the inside could influence the formation. The flakes were found to be less numerous although they retained a considerable size. Evidently the cracks did not take place during hardening from abnormally high temperatures.

For the purpose of studying the effect of temperature the steels were annealed in a current of hydrogen at 1850° F. for 7 hr. and quenched in water. The appearance of the sections after macrographic etching is illustrated at the bottom of this page. Flakes formed only in the alloy steel. The greater sensitivity of nickel-chromium-molybdenum steel than nickel-chromium steel is evident; large cracks are present in the former; although they are numerous in the latter, they are only a few millimeters in mean diameter.

The three steels were also annealed up to 30 hr. in a current of hydrogen at 1175° F. and up to 150 hr. at 750° F., in all cases followed by quenching in water. No flakes were obtained in any of them.

Experiments carried out after the publication of the original paper have demonstrated that flakes are also formed by annealing in a current of hydrogen diluted with nitrogen, and the sensitiveness of the steels tested to the formation of flakes decreases according to the dilution of hydrogen.

A summary of the results indicates that hy-



Carbon Steel *Nickel-Chromium Steel* *Nickel-Chromium-Molybdenum Steel*

Annealing 5 Hr. in Hydrogen at 1850° F. Is Insufficient to Cause Flakes to Form in Carbon Steel

drogen causes flakes to form in solid steel. The observations and experiments also exclude the other hypotheses brought forward in the matter, such as dendritic segregation and cooling stresses, not only as fundamental causes, but also as accessory causes. In other words, flakes have been formed in pieces free from flakes, free from a marked dendritic segregation, and in small pieces reduced largely in size by hot working.

Flakes form when pieces very rich in hydrogen are cooled very quickly. One can therefore infer that it is very difficult if not impossible to fix completely this gas in the metal in the solid state. Likewise absorption of hydrogen, which is considerable at a high temperature, decreases quickly when the temperature goes down, so that at 1475° F. the quantity absorbed even after 30 hr. is not sufficient to crack the material.

Gas Analyses Are Inconclusive

Actual analysis for hydrogen does not give conclusive results. For instance, some analyses of a nickel-chromium-molybdenum steel are as follows: The steel as received without flakes contained 0.00009% hydrogen. After annealing in hydrogen at 2100° F. for 14 hr. and cooling in air, the sample was free from flakes and contained 0.00008% hydrogen. Another piece annealed in hydrogen at 2100° F. for 21 hr. and cooled in the air had abundant flakes yet analyzed only 0.00006% hydrogen. Longer annealing (28 hr.) increased the hydrogen to 0.00010%. The steel, annealed for 7 hr. in hydrogen at 2100° F. and quenched in water, contained abundant flakes and had much more hydrogen, namely 0.00050%. These contents are extremely low and remarkably uniform both before and after annealing, if air cooled, no matter whether flakes are present or not. The value is higher in the hardened piece; however, it is less than the figure given by Sieverts, Luckenmeyer-Hasse and Schenck for saturation at 2100° F., namely 0.00070 to 0.00090%, and nearly nil at room temperature. Hence our values lead to the conclusion that slow cooling, such as to avoid the formation of flakes, or air cooling with the formation of flakes, eliminates hydrogen almost totally, but quick hardening in water fixes a good part of it.

According to the calculations of Luckenmeyer-Hasse and Schenck the pressure developed by hydrogen content can reach very high values, varying directly with the hydrogen content and inversely with the temperature. In practice, however, flakes form only at temperatures between 400 and 600° F. This can be explained either by admitting that the initial hydrogen content is such that the bursting pressure on dissolution overcomes the strength of the metal only at the temperatures included in that interval, or, neglecting any consideration of the initial hydrogen content, (provided it is over a determined limit) by supposing that some other phenomenon takes place causing conditions wherein the metal cracks.

Researches by Jaquerod and Gagnebin on the speed of diffusion of hydrogen in iron have shown that there is a discontinuity between 350 and 600° F. in which diffusion suddenly decreases 300-fold. If the iron had previously been heated in hydrogen above 1650° F., the drop is still greater; the iron passes from a permeable state to an impermeable state since the drop in the speed of diffusion is in the ratio of 10,000 to 1. It is logical to think that the two phenomena are closely connected because they take place in the same temperature interval.

The mechanism of flake formation could therefore be the following: The metal can contain a larger quantity of hydrogen at high temperatures than that which is necessary at lower temperatures to develop a bursting pressure, but as long as the rate of diffusion is high, this pressure cannot locally reach values such as to produce cracks with the usual speeds of cooling.

When the temperature is reached where the metal suddenly becomes impermeable, the hydrogen, except during extremely slow cooling, develops all its pressure locally and flakes are formed. The hydrogen can then escape through these cracks and will not show up in a gas analysis except when the cooling has been so quick as to fix a part of it in solution in the steel.

Our experiments on the three types of steel also show their enormous difference in sensitivity to the formation of flakes, and the influence which chromium, nickel and molybdenum have on it, and explains why flakes were first seen in nickel-chromium steels.

Since hot steels absorb hydrogen so easily, not only during their manufacture but also in later heating in atmospheres containing more or less of this gas, it is apparent that it must be kept in mind in appraising many of our modern processes. Bright annealing is frequently done in atmospheres high in hydrogen; copper brazing, so-called, is another such process. Hydrogen released during pickling also produces brittleness, either permanent or temporary. Evidently the gas in steel must be restricted to limits that are exceedingly low if harm is to be avoided.

The Chemical Elements and Their Discoverers

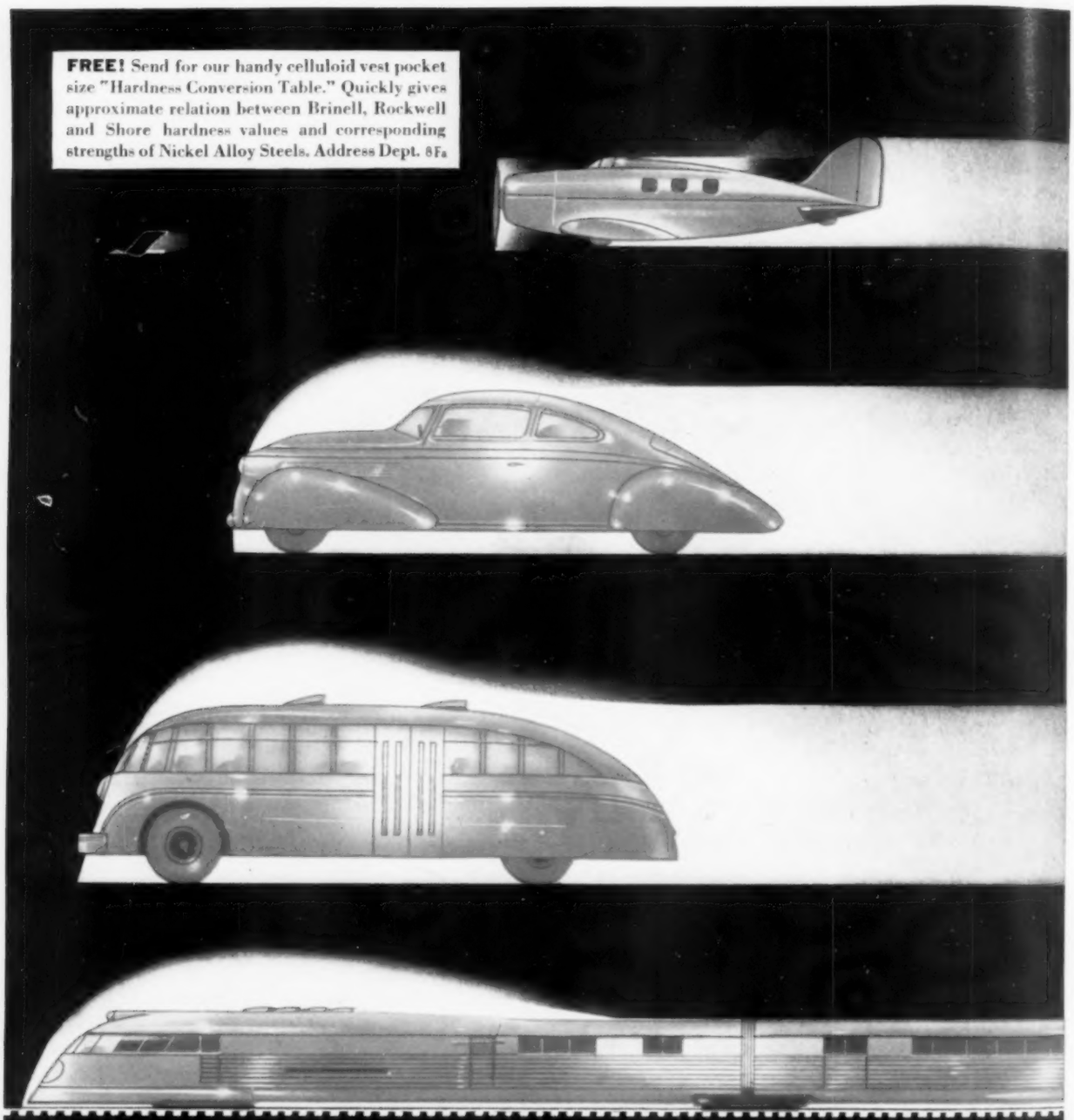
Compiled and Copyrighted, 1936, by George W. Muhleman

Courtesy Fisher Scientific Co.

Name	Isotopes	At. No.	Valence	At. Wt.	Discoverer and Nationality	Year
Actinium (Ac)		89	3	228	Debierne (F)	1899
Alabamine		85	8		Allison, Murphy (A)	1931
Aluminum (Al)	1	13	3	26.97	Orsted (Da)	1825
Antimony (Sb) (*Stibnium*)	2	51	3–5	121.76	Tholde (G)	1450
Argon (A)	2	18	0–8	39.944	Raleigh, Ramsay (E)	1894
Arsenic (As)	1	33	3–5	74.91	Albertus Magnus (R)	1250
Barium (Ba)	4	56	2	137.36	Davy (E)	1808
Berylllium (Be) (*Glucinum*)	2	4	2	9.02	Vauquelin (F)	1798
Bismuth (Bi)	2	83	3–5	209.00	Geoffroy (E)	1753
Boron (B)	2	5	3	10.82	Davy (E), Gay-Lussac (F) Thenard (F)	1808
Bromine (Br)	2	35	1–7	79.916	Balard (F)	1826
Cadmium (Cd)	6	48	2	112.41	Stromeyer (G)	1817
Calcium (Ca)	2	20	2	40.08	Davy (E), Berzelius (S), Pontin (F)	1808
Carbon (C)	2	6	2–4	12.000	Ancient	B.C.
Cerium (Ce)	2	58	3–4	140.13	Klaproth (G), Hissinger. Berzelius (S)	1803
Cesium (Cs)	1	55	1	132.91	Bunsen, Kirchoff (G)	1860
Chlorine (Cl)	2	17	1–7	35.457	Scheele (S)	1774
Chromium (Cr)	4	24	2–3–6	52.01	Vauquelin (F)	1798
Cobalt (Co)	1	27	2–3	58.94	Brandt (S)	1735
Columbium (Cb) (*Niobium*)		41	3–5	92.91	Hatchett (E)	1801
Copper (Cu) (*Cuprum*)	2	29	1–2	63.57	Ancient	B.C.
Dyprosium (Dy)		66	3	162.46	Boisbaudran (F)	1886
Erbium (Er)		68	3	167.64	Mosander (S)	1843
Europium (Eu)		63	3	152.00	Demarcay (F)	1901
Fluorine (F)	1	9	1–7	19.00	Scheele (S)	1771
Gadolium (Gd)		64	3	157.30	Marignac (F)	1880
Gallium (Ga) (*Gallia*)	2	31	3	69.72	Boisbaudran (F)	1875
Germanium (Ge) (*Germania*)	8	32	4	72.60	Winkler (G)	1886
Gold (Au) (*Aurum*)		79	1–3	197.2	Ancient	B.C.
Hafnium (Hf) (*Hafnia, Copenhagen*)		72	4	178.6	Coster (D), Hevesy (H)	1923
Helium (He) (*Helios*)	1	2	0–8	4.002	Janssen (F), Lockyer (E) Ramsay (E), Cleve (S)	1868 1895
Holmium (Ho) (*Holmia, Stockholm*)		67	3	163.5	Cleve (S)	1879
Hydrogen (H) (*Gr. Hydro*)	2	1	1	1.0078	Cavendish (E)	1766
Illinium (Il)		61	8–0		Hopkins, Yntema, (A), Harris, (C)	1926
Indium (In)	1	49	3	114.76	Reich, Richter (G),	1863
Iodine (I) (*Iodes*)	1	53	1–7	126.932	Courtois (F)	1811
Iridium (Ir) (*Iris, Rainbow*)		77	3–4	193.1	Tennant (E)	1804
Iron (Fe) (*Ferrum*)	2	26	2–3	55.84	Ancient	B.C.
Krypton (Kr) (*Gr. Kryptos, hidden*)	6	36	0–8	83.7	Ramsay, Travers (E)	1898
Lanthanum (La) (*Gr. Lanthano, to conceal*)	1	57	3	138.90	Mosander (S)	1839
Lead (Pb) (*Plumbum*)	8	82	2–4	207.22	Ancient	B.C.
Lithium (Li) (*Lithos, stone*)	2	3	1	6.940	Arfvedson (S)	1817
Lutecium (Lu) (*Lutetia, Paris*)		71	3	175.20	Urbain (F)	1907
Magnesium (Mg.) (*Magnesia, in Thessaly*)	3	12	2	24.32	Davy (E)	1808
Manganese (Mn) (*Magnes, magnet*)	1	25	2–4–6–7	54.93	Gahn (S)	1774
Masurium (Ms) (*Masurian, in Germany*)		43	7	96 (?)	Noddack, Tacke, Berg (G)	1924
Mercury (Hg) (*Hydrargyrum*)	7	80	1–2	200.61	Ancient	B.C.
Molybdenum (Mo) (*Gr. Molybdos, lead*)	7	42	3–4–6	96.0	Hjelm (S)	1781
Neodymium (Nd) (*Gr. Neos, New; Didymos, Twin*)	4	60	3	144.27	Welsbach (G)	1885
Neon (Ne) (*Gr. Neos, New*)	3	10	0–8	20.183	Ramsey, Travers (E)	1898
Nickel (Ni)	3	28	2–3	58.69	Cronstedt (S)	1754
Nitrogen (N)	2	7	3–5	14.008	Rutherford (E)	1772
Osmium (Os) (*Gr. Osme, Color*)	6	76	2–3–4–8	191.5	Tennant (E)	1804
Oxygen (O)	3	8	2	16	Priestly (E)	1774
Palladium (Pd) (*Planet, Pallus*)		46	2–4	106.7	Wollaston (E)	1803
Phosphorus (P) (*Gr. Light Bearer*)	1	15	3–5	31.02	Brand (G)	1669
Platinum (Pt) (*Sp. platina*)		78	2–4	195.23	Wood (E)	1741
Polonium (Po)		84	6		Marie and Pierre Curie (F)	1898
Potassium (K) (*Kalium*)	2	19	1	39.10	Davy (E)	1807
Praseodymium (Pr) (*Gr. praseos, Green; didymos, Twin*)	1	59	3	140.92	Welsbach (G)	1885
Protoactinium (Pa)		91	5		Soddy, Cranston (E), Hahn, Meitner (G)	1917
Radium (Ra) (*Radius, ray*)	4	88	2	225.97	Marie and Pierre Curie (F)	1898
Radon (Rn) (*Niton*)		86	0–8	222.00	Dorn (G)	1900
Rhenium (Re) (*Rhine prov.*)	2	75	7	186.31	Noddack, Tacke, Berg (G)	1924
Rhodium (Rh) (*Gr. Rhodon, rose*)		45	3	102.91	Wollaston (E)	1803
Rubidium (Rb) (*Rubidus, red*)	2	37	1	85.44	Bunsen, Kirchoff (G)	1861
Ruthenium (Ru) (*Ruthenia, Russia*)	7	44	3–4–6–8	101.7	Klaus (Ru)	1844
Samarium (Sm) (*Samarski, a Russian*)		62	3	150.43	Boisbaudran (F)	1879
Scandium (Sc) (*Scandinavia*)	1	21	3	45.10	Nilson (S)	1879
Selenium (Se) (*Gr. selene, moon*)	6	34	2–4–6	78.96	Berzelius (S)	1818
Silicon (Si) (*Silex, flint*)	3	14	4	28.06	Berzelius (S)	1823
Silver (Ag) (*Argentum*)	2	47	1	107.880	Ancient	B.C.
Sodium (Na) (*Natrium*)	1	11	1	22.997	Davy (E)	1807
Strontium (Sr) (*Strontian, in Scotland*)	3	38	2	87.63	Crawford, 1790, Davy (E)	1808
Sulfur (S)	3	16	2–4–6	32.06	Ancient	B.C.
Super-Uranium		93			Fermi (I)	1934
Tantalum (Ta)		73	5	181.4	Ekeberg (S)	1802
Tellurium (Te) (*Tellus, earth*)	4	52	2–4–6	127.61	Reichenstein (Au)	1782
Terbium (Tb) (*Ytterby, in Sweden*)		65	3	159.2	Mosander (S)	1843
Thallium (Tl) (*Thallus, budding twig*)	3	81	1–3	204.39	Crookes (E)	1861
Thorium (Th) (*God, Thor*)	8	90	4	232.12	Berzelius (S)	1828
Thulium (Tm) (*Thule, Northland*)		69	3	169.4	Cleve (S)	1879
Tin (Sn) (*Stannum*)	11	50	2–4	118.70	Ancient	B.C.
Titanium (Ti) (*Titanes, sons of earth*)	1	22	3–4	47.90	Gregor (E)	1791
Tungsten (W) (*Wolframium, heavy stone*)	4	74	6	184.0	d'Elhuyar Brothers (Sp)	1783
Uranium (U) (*Planet Uranus*)	8	92	4–6	238.14	Klaproth (G)	1789
Vanadium (V) (*Goddess, Vanadis*)	1	23	3–5	50.95	Sefstrom (S)	1830
Virginium		87	1		Allison, Murphy (A)	1930
Xenon (Xe) (*Gr. Xenos, strange*)	9	53	0–8	131.3	Ramsay, Travers (E)	1898
Ytterbium (Yb) (*Ytterby, in Sweden*)	1	70	3	173.04	Marignac (F)	1878
Yttrium (Y) (*Ytterby, in Sweden*)	1	39	3	88.92	Gadolin (Fi)	1794
Zinc (Zn)	5	30	2	65.38	Marggraf (G)	1746
Zirconium (Zr)	3	40	4	91.22	Klaproth (G)	1789

(A)—American (Au)—Austrian (C)—Canadian (D)—Dutch (Do)—Danish (E)—English (F)—French (Fi)—Finnish (G)—German (H)—Hungarian (I)—Italian (R)—Roman (Ro)—Russian (S)—Swedish (Sp)—Spanish

FREE! Send for our handy celluloid vest pocket size "Hardness Conversion Table." Quickly gives approximate relation between Brinell, Rockwell and Shore hardness values and corresponding strengths of Nickel Alloy Steels. Address Dept. 8Fa



Steeds of steel whose sinews are strengthened with NICKEL

Although Nickel Steels were the first alloys to be used in commercial quantities for mechanical applications, they have kept abreast of modern engineering developments and are extensively used in all forms of modern transportation.

THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N. Y.

CORRESPONDENCE

from home and abroad

Progress of Fusion Welding

PARIS, FRANCE — Considerable progress is being constantly made in the various processes of joining metals by fusion welding, not only in the welding methods, but also in the materials and equipment used. The logical consequence will certainly be an extension of welding applications throughout industry.

France consumes about 50 million arc welding electrodes per year, corresponding to the deposition of about 1600 tons of metal. Oxy-acetylene welding, in 1930, consumed nearly 100,000 tons of calcium carbide, which means that the processes are about equal in importance. Progress has been considerable since 1920, for instance, when 46,000 tons of calcium carbide were used.

To make a satisfactory welded metallic structure or machine part it is necessary to choose first the proper welding process — arc, acetylene, resistance, thermit — for each has its distinct and well-defined field of application. The process having been determined, the method and equipment most appropriate to the intended application of the part must then be adopted. Metallic structures which are submitted to no particular loads do not require the same quality of weld as is essential for pressure vessels, for instance, which must withstand high temperatures, shock, corrosion and stress simultaneously.

A particularly interesting oxy-acetylene method known as "double bead vertical welding" *(soudure montante à double cordon)* has been invented and put into practice at the Central Bureau of Autogenous Welding in France. It is intended especially for steel construction where safety and sound joints are imperative. Simple visual inspection during the process indicates the quality of the joint. A sketch on the next page illustrates the principles.

The edges of the pieces to be joined are brought into position and the assembly placed so the seam will be vertical. A hole a few millimeters in diameter is melted through at the bottom edge of the abutting pieces; this small hole must be maintained during the course of the operation, being continually melted ahead of the ascending blowpipe. In this way the total thickness of the plate is fused through, and a second continuous bead appears on the rear side when the welding is correctly executed, as well as a ripple weld of normal appearance on the operator's side.

The use of this method avoids adhesion, for the top edge of the flame goes through the hole, sweeping out slag and oxides that appear at the surface of the molten metal. Neither does the flame impinge on the sides of the welded joint, heating them unnecessarily. This method is excellent for joining thin plates averaging ⅛ to ¼ in. thick.

Modifications have also been devised for thicker plates, requiring two operators working simultaneously on each side, and each flame penetrating half the thickness. This method is also indicated in the sketch below.

Numerous applications of this new method have been found: More than a million cylinders

for compressed gas, some gas holders, and a number of large pressure vessels. Locomotive frames made of 1¼-in. plate have also been repaired, using the method where two operators work from opposite sides.

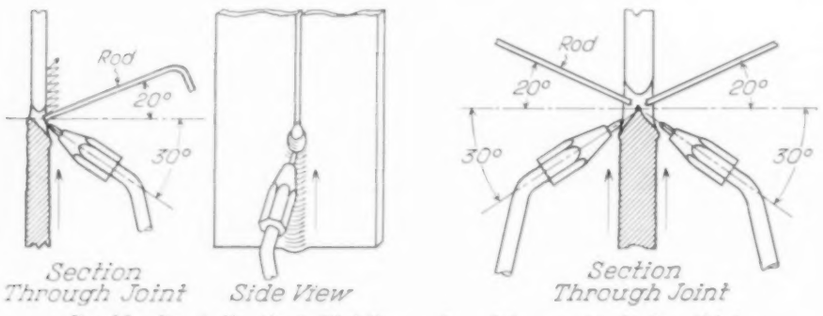
Electric arc welding has also shown remarkable progress in recent years. A wide choice of electrodes applicable to almost any type of work is available. Heavy slag-forming coatings and volatile or semi-volatile coatings have been developed, providing excellent properties in the deposited metal. A fine piece of work was recently completed with them — a fractionating tower for oil cracking, 75 ft. high, 9 ft. diameter and 66 tons weight. It is made of 1½-in. steel plate (tensile strength 65,000 psi.) entirely welded by the metallic arc process. After welding, it was normalized for stress relief in a large and appropriate furnace.

Among other interesting constructions, we may note the housing project "Cité de la Muette" at Drancy in the suburbs north of Paris. It comprises three important groups of buildings; the whole contains 1200 dwellings to accommodate 4000 to 5000 persons. These buildings have a frame made of bent and welded steel plate, in standardized pre-fabricated sections. Walls are constructed of reinforced concrete slabs poured into metallic molds in a central yard. These are taken to the site and affixed to the frame by welding at the reinforcing, which projects from the four edges.

These few examples, taken from various fields, indicate the rapid and continued progress in the technique of fusion welding.

France has not yet constructed any completely welded bridges, such as those built by some of the other European countries. However, some interesting work has been done in the repairing and reinforcement of existing ones.

ALBERT PORTEVIN



Double Bead Vertical Welding. In plate up to ¼-in. thick, a small hole, completely perforating the joint, is maintained above the flame; in thicker plate (up to 1½ in.) two oxy-acetylene blowpipes work from opposite surfaces simultaneously

Ultra-Sound Waves for Locating Inner Defects

GROSNY, U.S.S.R. — Much has been written about the use of X-rays and gamma-rays for discovering hidden defects in metal products, weldings and assemblies. It has such great technical importance that the similar use of other penetrating rays warrants investigation.

It is known, for instance, that ultra-sound waves (or, better, supersonic vibrations) are transmitted through almost any amount of liquid or solid at characteristic velocities. Such vibrations are used, for instance, for sounding in lakes and in the sea. Modern passenger liners and warships have automatic devices where the captain is continually informed of the soundings by a measurement of the time for the echo to return of a supersonic wave, emitted from the ship's hull. Consequently S. J. Sokolov of the Soviet's Central Radio Laboratory has proposed that such waves be used to examine metal. While the project is still in the developmental stage, it has sufficient promise and interest to warrant a preliminary note.

It should first be proper to describe how such rapid vibrations, of frequency far above that which can be detected by the ear, are excited. For this I quote from "Modern Physics" by G. E. M. Jauncey.

"A crystal of the mineral quartz (SiO_2) has the shape of a hexagonal prism with a hexagonal pyramid at each end. The line connecting the apex of one pyramid to the apex of the pyramid at the opposite end is known as the principal axis. In addition to the principal axis there are three electrical axes perpendicular to the principal axis and at an angle of 60°, each to each.

"If a slab of quartz is cut with its thickness parallel to an electrical axis and this slab is subjected to pressure in the direction of its thickness, one face becomes charged positively and the other negatively, and there is developed a difference of electrical potential between the two faces. If, instead of a pressure, a tension is applied, a negative charge is developed on the first face and a positive charge on the second face. This phenomenon is known as the piezoelectric effect.

"On the other hand, if the two faces of the quartz are in

contact with metal conductors and a difference of potential is set up between the conductors by any means, a contraction or expansion (depending upon the direction of the potential difference) is produced in the quartz plate. This phenomenon is known as the inverse piezoelectric effect.

"If an alternating voltage is applied to the crystal plate, the plate alternately contracts and expands so that elastic vibrations are set up. If the frequency of the elastic vibration is equal to the frequency of the alternating voltage, vibrations of large amplitude are set up in the quartz. Violent oscillations may be set up in a quartz plate 1 cm. thick in the direction of the electric axis by electrical impulses occurring at the rate of 287,000 per sec. or any multiple thereof.

"Because of the piezoelectric property of quartz and because of the fact that quartz plates can be set into violent oscillation by the application of an alternating frequency, quartz plates are used to stabilize the frequency of electrical oscillations in radio circuits."

Prof. Sokolov has experimented with beams of supersonic waves of 500,000 to 1,200,000 vibrations per second. Such a beam passes freely through uniform metal, but is reflected and dispersed when sudden changes in "accoustic hardness" take place — for example, at the surface of the metal in air or at discontinuities within the body of the metal.

The problem of making ultra-sound waves visible is not insoluble. For this purpose the ripples on the quiet surface of transformer oil may be observed, ripples occurring when supersonic waves are emerging. These ripples can be seen if the surface of the metal object is coated with transformer oil, or it is dipped bodily into a tray of oil. Transformer oil is a good conductor for ultra-sound waves and the latter, on their passage through the metal-oil interface, alter their intensity but little. (Liquid mercury is also an excellent transmitting medium.) An undampened ultra-sound ray produces a multitude of minute ripples on the surface of the oil or mercury and these are absent where the ray is dampened. Oil ripples may be readily photographed in light reflected at a rather flat angle when the frequency is above 100,000 per sec., even when their intensity is very small.

Experiments are in progress to show the sensitivity of the process — that is, the size of defect which will produce a "shadow." Apparently there is no limit to the length of metallic path. Supersonic waves were easily observed at the far end of a steel bar 27 in. long. In another experiment four steel cylinders each 10 in. high were placed one upon another so that the total height made 40 in. The surfaces of contact had been oiled, and penetration of ultra-sound waves through the length of the four cylinders has been observed. When the abutting surfaces were not oiled, waves did not penetrate.

In order to get an idea of the width of internal defect that might be discovered, two metal plates each 1 in. thick were placed with their dry surfaces one upon another. These surfaces had first been ground to an accuracy of 0.0002 in. Ultra-sound waves did not pass through both the plates except when the surfaces had been oiled.

In these experiments the vibrating quartz crystal is immersed in oil so that the principal beam is directed vertically. Immediately above it is a suitable ball bearing upon which rest the parts to be tested.

B. M. Sustov

Evaluation of Toughness Under Low and High Speed Loadings

SPRINGFIELD, Mass. — Toughness, although scientifically undefined, has commercially been associated with plasticity. Thus the elongation or reduction of area in the tension test, the angular deformation in the torsion test, the deflection in the transverse loading test and the common bend test are generally interpreted and used as measurements of toughness. However, as pointed out by Heindlhofer, these various test methods produce different relationships between normal and shear stresses which may result in a single material being tough in one test and brittle in another, when judged by plasticity.

In the Charpy and Izod impact tests at least three distinct components influence the absorption of energy which, subtracted from the kinetic energy of the moving pendulum, gives a commonly used measurement of toughness. These tests appear to have very restricted usefulness, particularly on hard steel, since they do not permit separate evaluation of these three components — strength, plasticity and participating volume — and they are furthermore applicable only under notch conditions of precise shape and size.

In the light of experience in the shop, it is difficult to avoid the conclusion that high toughness (as defined in the first paragraph), particularly in tool steel, not only is undesirable but many times is the chief cause of failure. This condition arises from the apparent impossibility

of increasing toughness in a single material without a corresponding sacrifice of strength. The one exception seems to lie in the hardening of steel, not by ordinary quenching and tempering, but by the direct transformation method of Bain and Davenport, wherein the metal is quenched in a heated bath at, say, 600° F. This method, however, has limitations as to mass.

As examples where high "toughness" has been the sole cause of failure, we might cite three not uncommon cases: (1) Punches which upset; (2) striking dies whose impressions sink; and (3) drills and taps which distort angularly.

The ability to absorb energy under dynamic conditions without fracture is obviously a very desirable property. Recently H. C. Mann of Watertown Arsenal has shown an excellent method of evaluating this property up to certain limited velocities of testing (see METAL PROGRESS, March, 1935). He constructs a stress-strain curve in tension, using the actual stress in the least diameter or neck of the specimen and measures the area between the curve, the horizontal axis, and the vertical ordinate at the point of breaking.

However, this relationship between area under a corrected stress-strain curve and energy absorbed in an impact test holds good only up to certain velocities of impact. Passing this velocity, the ability to absorb energy or shock falls to very low values, in spite of the fact that the metal continues to possess high "toughness." Under loads delivered at high speeds the capacity of most materials to absorb energy is therefore independent of "toughness," as usually interpreted, and while "toughness" is not categorically shown undesirable, it definitely is not conducive to improved values and will not serve for selection of materials or heat treatment for locations where high speed loading must be resisted.

Under static or low speed loads, toughness or plasticity is a major component of the capacity to absorb energy. Moreover, it is to be remembered that an increase in either strength or plasticity (toughness) results in an increase of this capacity to absorb energy. Unfortunately an increase in either strength or plasticity generally results in a reduction of the other factor. More unfortunate is the fact that if an attempt is made to increase this capacity to absorb energy at more than 20 ft. per sec. by appreciably increasing the toughness (plasticity), a different sort of failure will result.

Virtually all reported tests of mechanical properties, with the exception of those by Mann, most certainly fall in the static or low speed classification. Static tests include those in tension, torsion and transverse loading, while low speed loads embrace the Charpy, Izod and torsion impact (all less than 20 ft. per sec.) and no information that cannot be gained under static conditions is yielded by the latter.

These three ordinary impact tests permit only integrated values and yield no relative information on strength and toughness. If such measurements are used as an index to selection or heat treatment, it is conceivable that materials capable of accommodating themselves to the load without fracture could be selected, but to undergo this load successfully, the material might plastically distort a prohibitive amount. The high toughness component which has contributed to a high figure of energy absorption has caused failure in being utilized.

It is not implied that the properties of glass, combining high strength with negligible plasticity, are desirable. Inasmuch as capacity to absorb energy is measured by an area limited by the two components stress and strain, plastic and elastic flow of more than an infinitesimal amount is necessary to avoid extremely low areas even with tremendous strength.

This discussion suggests three fairly tenable conclusions which are supported by the small amount of available evidence:

1. That static or low speed tests showing high toughness or high energy capacities are not only unreliable but misleading indexes for application under really high speeds.

2. That for static or low speed application only those tests which permit of separate evaluation of the several mechanical properties are helpful, since several types of failure are possible. The fallacy of using the product of undetermined individual components is obvious.

3. That both static and high speed velocity tests are essential to reveal the true capacities of the material.

ROBERT S. ROSE

Selective Nitriding

TURIN, ITALY — There is an increasing number of cases where nitriding is applied to machine elements of complicated design, in which certain well-defined portions of the surface must be protected against nitriding.

When absolute protection is not required, a paste containing finely pulverized lead and tin may be used. It will give satisfactory results, from the point of view of the exact limitation of

the protected areas, provided the layer of paste is very uniform and not too thick.

But when complete protection is required, the use of a tin coating becomes necessary. Many trials have shown that the application of tin in the molten state — either by dipping the part to be protected in molten tin, or by applying the tin with a soldering iron — may cause many serious difficulties, mostly due to the impossibility of obtaining a perfectly uniform layer, not exceeding certain limits in thickness. An excess is likely to spread outside the boundaries of the originally coated surface when the piece is hot.

Practically all these inconveniences can be avoided by electrolytic tin deposits, as proved by extensive experiments made recently on some especially delicate operations. The best results have been obtained with acidulated solutions of stannous chloride or sodium stannate. [Hothersall and Bradshaw recommend alkaline sodium stannate for its high throwing power; see METAL PROGRESS, January, page 39. — EDITOR.]

The surface of the pieces to be nitrided — after the usual complete cleaning of grease, rust and scale — is coated with a resinous varnish on those areas that must be nitrided and, therefore, to be protected from tinning. The pieces are then treated for about a minute in an electrolytic alkaline bath to take off last traces of grease. An imposed potential of 6 to 8 volts, with a current density of 60 to 70 amperes per sq.ft. (6 to 7 amp. per sq.dm.) is suitable. The pieces are then washed in running water, and attached to the cathodic terminal in the tinning bath.

When operating under a potential of about 3 volts and with a current density of 5 amperes per sq.ft. (0.5 amp. per sq.dm.) the penetration of the tin and the thickness of the coating obtained in about one hour is sufficient for complete protection against nitriding, and at the same time avoids any danger of an excess of tin.

The pieces are then washed in boiling water in order to remove the varnish from the areas to be nitrided, dried, and put in the nitriding box.

One of the greatest advantages of this process lies in the fact that it will protect, locally, well-defined small areas on the steel surface, even when these parts are located in places like the interior of small holes where the use of a soldering iron is difficult or even impossible. An important example is the selective nitriding of cylinders for pneumatic tools or small gas engines, where inlet and outlet ports must be finished by machining after hardening.

FEDERICO GIOLITTI

Gage of Metal for Enameling

WASHINGTON, D. C. — The subject of the proper gage of enameling iron to use for various products is one that has caused almost as much discussion and as many headaches as the subject of de-enameling. A recent editorial note in METAL PROGRESS was absolutely right in saying that the chiselers will be the greatest enemy of the young steel plumbing ware industry.

A few years ago a conference of enamelers was held at one of the large universities. One of the subjects for discussion was "Chipping." During the course of the meeting the representative of a large kitchen ware plant which had advertised its ware extensively was asked to comment. He stated that the success of his company with the better grade of ware was due to the heavy gage of steel that was used as a base. Eighteen-gage was used for this better ware, while 24 and 26-gage was used for the cheaper products. Then he made this cryptic statement: "If the kitchen ware people had used the proper gage of metal in recent years they would have produced a much better product, sold only slightly less number of pieces, and made a much larger profit." Furthermore, in my opinion, they would have helped to minimize rather than accentuate the chipping problem, which is always confronted to some extent in porcelain enameling.

It is understood, of course, that many other factors are required to produce a satisfactory enamel on steel sheets. Assuming that the metal surface is properly prepared and the enamel is right, I believe that a relatively thin coating of enamel (0.015 to 0.025 in.) will not chip unless the metal base is stressed to the point where it actually deforms. Of course, this deformation may be very slight, but the metal must be moved beyond the point to which it would naturally return when the strain is removed. That, to my notion, is the secret of the success of cast iron as a base.

The enamel industry is pretty busy in its own research problems with the chemistry of enamel application, and being a small industry, cannot afford much work on the fabrication of steel, or its proper surface texture. Vitreous enameling of steel presents the one time-tested method of preventing rust. By the use of enamel, new markets will be opened for sheet steel that may help to absorb the product of the many new continuous mills.

CHARLES S. PEARCE

ABRASION RESISTANCE

of a low alloy steel

(medium manganese)

By F. A. Wickerham
Metallurgical Department
Pittsburgh District
Carnegie-Illinois Steel Corp.

ABRASION has always been a problem and a source of much trouble in poorly lubricated bearings on moving parts, and in all equipment handling abrasive materials such as coal, coke, ore, sand and gravel. Replacement of worn parts is a serious economic factor in many industries, both on account of the cost of the renewals and the losses incident to interruption of operations while making repairs. Various materials, metallic and non-metallic, have been tried where abrasion is severe — some proving a success under particular conditions but a failure under others.

In the selection of materials for parts exposed to abrasive forces, it should be borne in mind that the hardness, as represented by Brinell number, or the tensile strength is not truly indicative of its durability. As an example of this fact, wear or abrasion tests made on different steels under one set of carefully standardized conditions have shown that one of them, having a Brinell hardness and tensile strength approximately 50% as great as a second one, had 76% the resistance to abrasion. A third steel, with 10% higher tensile strength than the second mentioned, was only 83% as resistant to abrasion, or only 7% better than the first steel of less than half its tensile strength. It is therefore evident that factors other than the ordinary physical properties determine the ability of a steel to resist wear or abrasion.

While there is no general agreement among metallurgists as to what these special factors are (nor, in fact, agreement among testing engineers as to the best way to measure wear resistance) the following theory by W. A. Wissler is quite illuminating:

"The local temperatures developed by cutting or friction are much higher than is commonly believed. Cutting edge temperatures of tools at work can be measured by using the tool and billet as the two elements of a thermocouple, and such measurements have shown temperatures over 1100 ° F. Other tests under conditions more nearly approaching those existing in production shops, have shown even higher temperatures. It is obvious that alloys that remain harder under such conditions will permit faster and more severe operating conditions and will also have a longer life. Although much more difficult (or often impossible) to measure, the surface temperatures developed in a crusher or by abrasive wear are probably equally high.

"The mechanism of wear may thus be partly explained by saying that the molecules or atoms forming the surface or edge become softened by heat and are torn or worn away while in relatively soft condition. This will also explain why

hardness measured at room temperatures is not a reliable indication of the ability of the material to resist wear. Hardness at a red heat — much more difficult to measure — is doubtless a better criterion."

Attempts to increase resistance to abrasion include not only selection of material but also various treatments. Among the materials used to resist abrasion are chilled and alloy cast irons, high manganese and other alloy steels, and hard non-ferrous alloys and carbides, sintered or welded together. Parts made of common and alloy steels may be prepared by various heat treatments, by hard facing with intrinsically hard materials such as stellite, or by nitriding or case hardening. Each of these materials and processes has merit under certain conditions, but none can be considered for all possible applications on account of the cost, weight or other inherent properties.

Chilled cast iron or alloy cast irons are somewhat expensive and can be used only when the part can be cast in the desired form. Otherwise, flame cutting or grinding to shape must be resorted to in those castings too hard to cut in machine tools. Since hard castings lack either the strength or ductility of structural steel, the castings must be heavier in section than rolled or forged steel. Therefore, where weight is of prime importance, these materials are badly handicapped.

Alloy steel high in manganese content, 11 to 14%, often termed Hadfield's manganese steel, has excellent abrasion resistance under certain conditions. This steel has the peculiar property that it hardens when the surface is cold worked in service; its soft austenitic microstructure, as heat treated, spontaneously transforms to hard martensite during the plastic deformation. In applications where this condition exists, the steel has most unusual resistance to abrasion; typical examples are jaws for rock crushers and railroad frogs under heavy traffic. However, in other applications where the service is a simple grinding without heavy impact, its abrasion resistance is not sufficient to justify its much higher cost; coal chutes and sand blast nozzles are examples. Also, the low elastic limit of this steel necessitates the use of heavier sections to give the desired rigidity. It should also be mentioned that cast manganese steel presents difficulties in fabrication; particularly, machining requires super high speed tools, and massive equipment — in fact, cutting is usually confined to that which can be done with an oxy-acetylene flame or a grinding wheel.

Special alloy steels (principally high carbon, high chromium steels) with or without heat treatment, have solved some problems of abrasion. Hard facing, nitriding and case hardening also have their special applications, but they are either too expensive or their use is impracticable in many places where a large amount or wide area of abrasion resisting material is desirable.

The materials or methods of treatment cited above represent attempts to provide equipment for special applications where initial cost is not the determining factor or the abrasive action is of a particular type. To provide a durable yet low priced steel for general applications has been a difficult problem. After a thorough study of various requirements, the Carnegie-Illinois Steel Corp. developed an abrasion resisting steel, which is designated in the trade by the initials "AR". It has now been on the market for approximately five years, during which time it has been used for numerous purposes, enjoying many repeat orders and an increasing demand.

This steel is a medium manganese steel of 0.35 to 0.50% carbon, 1.50 to 2.00% manganese, a maximum of 0.050% phosphorus and 0.055% sulphur, and 0.15 to 0.30% silicon. It is thus quite similar to the medium manganese rail which has been bought in large tonnage by certain eastern railroads or the S.A.E. steel T-1345 used more and more widely for heat treated parts. (When atmospheric corrosion is also a problem, this steel can be supplied with a minimum of 0.20% copper, in which case its corrosion resistance will be on a par with that of copper-bearing structural steel.) It is available in standard bar sections, structural shapes, universal and sheared plates, and in strips up to 36 in. wide.

In the as-rolled condition, "AR" steel has a tensile strength of approximately 100,000 to 125,000 psi. and a Brinell hardness of 200 to 250, depending upon the gage, the lighter gages usually showing higher physical properties than the heavier ones. While this steel is primarily designed for use in an untreated condition, it may be heat treated to give tensile strengths up to 150,000 psi. with good ductility.

One of the requirements of abrasion resisting steel for general application is that the steel must be capable of being fabricated by the usual shop equipment and practices. Experience is now available from many different applications, and has demonstrated that it can be fabricated by only slightly modifying the regular methods. As it is a steel of higher tensile strength than the plain carbon steels familiar to all fabricating

shopmen, more power is required for shearing, punching and cold forming, and it is necessary to observe the following precautions, particularly with the heavier gages:

Like other high tensile materials it must be handled carefully. In shearing short lengths in gages up to 1 in., the steel should be preheated to approximately 600 to 800° F. (Physical properties will not be affected by this low heat.)

Gages heavier than 1 in. should be flame cut, but since this medium manganese steel has air hardening characteristics, it should be preheated to at least 625° F. immediately before flame cutting and it should be stress relieved by reheating after flame cutting. Where it has not been practicable to heat the entire plate, satisfactory flame cutting has been done by preheating the portion of the plate to be cut with a torch before cutting and then reheating the cut portion after the flame cut is finished. Other methods of heating may, of course, be employed with equally good results, since the object is merely to prevent rapid cooling of the cut edge.

Fabrication Properties

It can be satisfactorily cold punched in gages of ⅜ in. and under, but, as pointed out, more pressure will be required and the life of the punches will be shorter. After punching, the holes should be reamed to eliminate fine cracks around the hole. Where the service requires holes close together and when the punching cannot be done hot, due to size of hole, lack of heating facilities or other reasons, the holes should be drilled.

Drilling and machining can be done with standard equipment, but the speeds and feeds must be reduced, as is necessary with any high tensile steel. High speed drills are necessary with a flood of drilling compound to cool the drills. The clearance rake of the drill should be less than for softer steels.

As in shearing any high tensile steel, minute cracks or nicks are left in the sheared edge, especially on the shear drag side. If cross bending or cold forming of any kind is attempted with the edges in this condition, these incipient cracks are likely to be opened and further extended, even causing complete failure of the section. Therefore, when the steel is to be cold formed, the burr should be removed from any sheared edges with a grinder or file, working in a direction parallel to the edge of the plate. This direction is important; plates have been known to crack if the grinding wheel is working at right angles to the flat.

Actual shop experiences have shown that prior to severe cold bending or forming up to and including ½ in. thickness, "AR" steel should be heated to between 1200 and 1300° F. and cooled slowly in the air. The abrasion resistance of the steel is not affected by heating to these low temperatures. It can also be hot formed without affecting the abrasion resistance, provided the steel is not heated to a temperature over 1500° F. After heating, the work should be done promptly and completed before the steel has cooled below 950° F. Definite rules as to when to prefer hot forming rather than cold forming can hardly be stated to suit all cases; usually this is best determined by trial.

As to heat treatment of sections over ½ in. and up to 1⅛ in. thick, more satisfactory results are obtained if the material is heated to 1475 to 1525° F., quenched in water and then drawn at 1100 to 1150° F. To avoid cracks the part or assembly should be quenched in water for 30 to 60 sec., depending upon the size, then allowed to cool in air to about 600° F., and drawn back immediately.

Satisfactory welds may be made with proper welding technique; the assemblage should be stress relieved after welding. Such welding rods as Fleet-Weld No. 85, Tank-Craft, Murex High-Manganese-Molybdenum, Murex Special "A", American Steel and Wire Co.'s Premier HC and Premier Hard Surface, Metal and Thermit's Universal, General Electric's No. 84, No. 85, type "O" and W-20, have been used with entire satisfaction. Probably there are a number of other welding rods and electrodes which would give satisfactory results.

"AR" steel has been used successfully in coke handling equipment, chutes for handling coal, ore, rock, gravel and sand, for screens, concrete mixer parts, bucket lips, teeth and links on ditching machines, furnace skips and hoppers, pug mill liner plates, dredge pipe, pontoon pipe, conveyor troughs and parts and other applications where abrasion is the principal factor causing early break-down of ordinary steel or cast iron. These applications have been closely watched by the steel producer; reports from customers indicate very satisfactory results, the life often being two or three times that of the plain carbon steel formerly used. Considering both the initial cost and the increased life of parts, the use of this medium manganese steel for the many purposes cited has been fully justified.

Story of

DROP FORGINGS

(Connecting Rods)

Pictorial Supplement to

METAL PROGRESS

July, 1936

TEXT BY MYRON WEISS PICTURES BY VAN FISHER

AT THE PLANT OF STEEL IMPROVEMENT & FORGE CO., CLEVELAND

This season at last wise men of business are again hearing the heart beat of industry which, like physicians who auscultate the human chest for the lub-dub sound of the healthy heart, they have long sought. Those business men now hear the vibrant thud and crash of steam hammers as they beat out forgings, and send those corpuscles of industry into the arteries of the Nation's commerce.

Forging, casting, rolling, machining, welding — these are the ways of making metals useful to mankind. Each has its particular values in the processing arts for turning out large numbers of objects of relatively simple shape, objects which range from toys to locomotive parts. Of them all the manufacturing process which usually is most efficient and economical for parts of great reliability is that of forging.

In the following pages of this special supplement, "Metal Progress" tells by picture and text how painstaking men make such industrial corpuscles. The example will be the drop forging of connecting rods for motor-truck engines.

Stacked nearby the hammers are duplicates, or blanks — the raw material of forging — sheared from bars. Forging steel is rolled to proper size from forging-grade billets — carefully made, high grade steel, closely conforming to chemical and physical specifications for the jobs the finished forgings will have to perform. Inner structure must be sound and clean; surface must be excellent.

After mechanical engineers have prepared the drawings and metallurgists have approved the steel and specifications for heat treatment, the die sinker goes to work. He is a man of infinite patience and skill, with a mirror imagination who can see in reverse the pattern given to him. His job is to cut an intaglio of the pattern into blocks of steel, half in one, half in another. That steel must withstand tremendous blows of the forging hammer. It must be uniformly hard throughout. Yet it must be soft enough to yield to the cutting edge of routing machine and file.

The die is made in upper and lower blocks. Lead is run into the cavity and the trial casting carefully measured. Then careful scraping perfects the womb of the die.

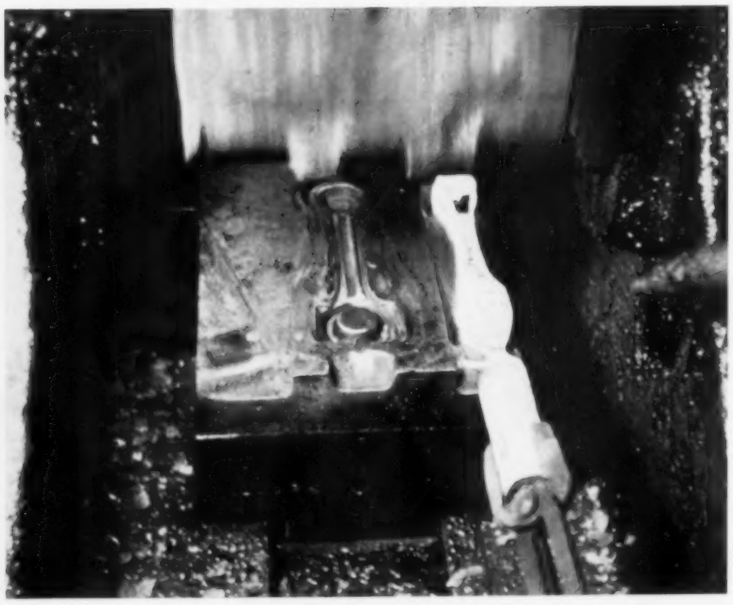
When the dies are mounted in a hammer — one to a moving ram, the other to the solid anvil — the forging is ready to run.

Into one end of a furnace go the blanks. Blazing gas beats whitely upon them until they are at forging heat. They must not melt, or even get so hot that the grain of the steel increases unduly in size and changes the nature of the metal. They must not be scaled excessively and the scale must be loose and flaky. There is a best degree of heat and an accurate control of combustion gases which the learned metallurgist determines beforehand, which the alert hammer man maintains by pyrometer, valves and gages.

At that instant man and hammer become a synchronized team. With long tongs, gripped in mighty hands and sinewed wrists, the furnace man hauls the white hot steel from the furnace, swings it to the lower die block. The finishing impression — the true die — is in the center. A fuller is at the left side, an edger at the right.

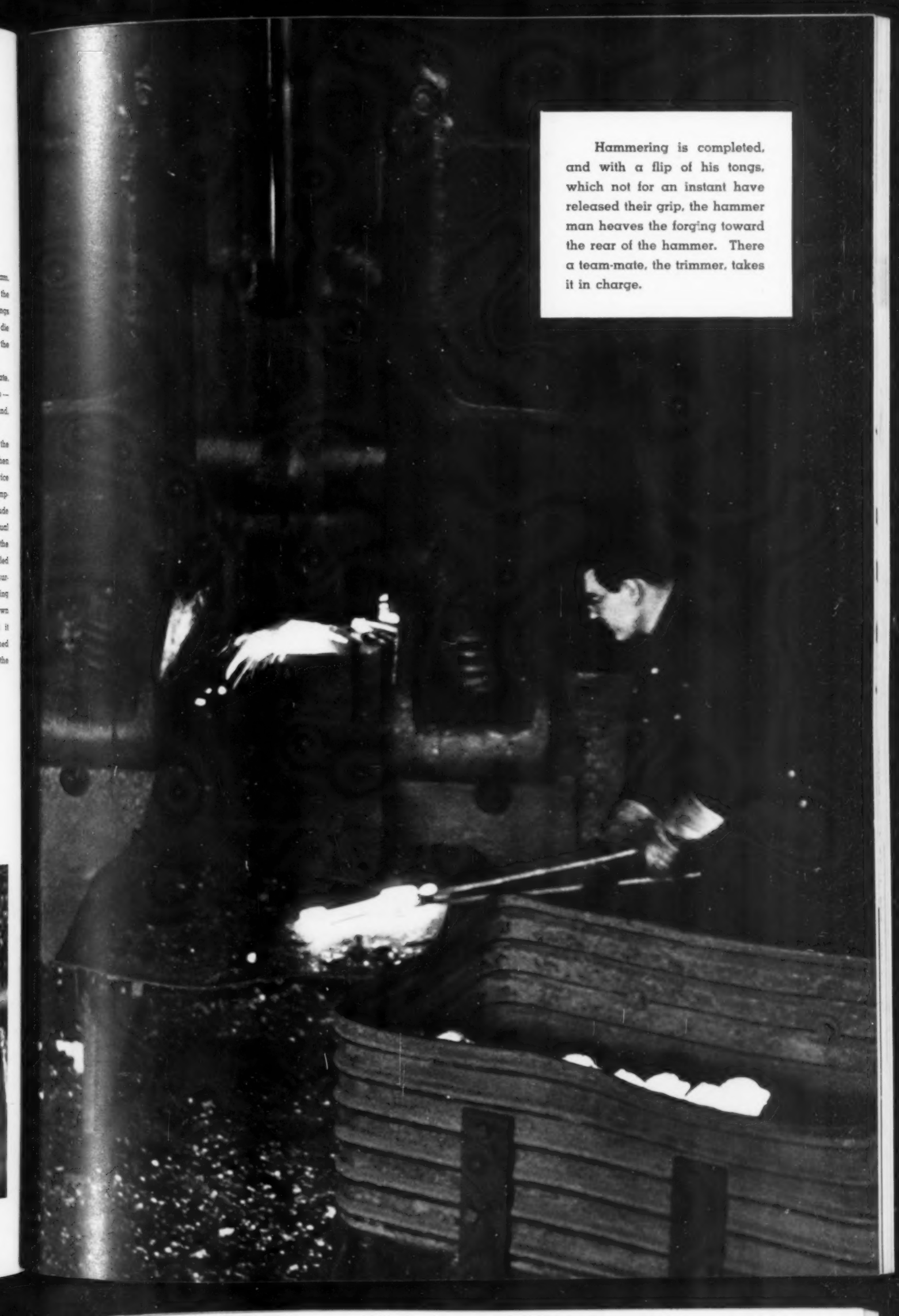
Upon the fuller the hammer man holds the radiant duplicate. Down and up goes the hammer, down and up, down and up — four times. After each blow the steel is rolled quarter round, necked and worked, acquires the shape of something.

Over into the edger the workman's strong grip then swings the forging. Twice descends the hammer, lumping up the metal to a crude approximation of the eventual connecting rod. Quite hot the metal still is. But a crackled scale is forming upon its surface — runic signs of cooling — only to be quickly blown off by a jet of air, lest it scour and wear the finished die or embed itself into the surface of the steel.



The hammer man does not pause an instant. Into the finishing die, he swings the forging. Down slams the hammer, again and again and again, with increasing power and compulsion. Metal rams into every crevice of the die. Excess metal spreads into a shallow gutter cut around the edge and forms a fin, or flash, around the parting line between the dies.

When the hammer makes its final blow the temperature of the forging is much closer to that critical point where the steel recrystallizes internally. Yet the metal must not be too cool, for it will become so stiff it will unduly wear the die. In balancing two desired yet contradictory aims lies the forge man's art — a hot metal for easy work and long die life, yet worked down cool enough for a fine, tough grain in the finished forging.



Hammering is completed, and with a flip of his tongs, which not for an instant have released their grip, the hammer man heaves the forging toward the rear of the hammer. There a team-mate, the trimmer, takes it in charge.

The trimmer's primary job is to remove the flash of the forging. This he accomplishes by putting the whole piece in a press whose upper head, descending, drives the forging through a tight-fitting trimming die which shears off the flash for scrap.

A connecting rod must endure brutal work. It is a vital part of a motor. Therefore it is heat treated to remove internal strains in the steel, refine the granular structure, and enhance its strength and toughness. Before it cools from the tempering heat it is hammered further in a finely machined restriking die to bring it closer to dimension and remove any small warp that may exist.

Last stage in the forge shop is inspection. A keen-eyed, diligent, conscientious man tests each forging for proper hardness, proper size, proper weight. Hardness is a measure of strength and machinability — once the composition of the steel and its heat treatment is fixed. Any tiny surface imperfection, seat of future trouble, warrants discard.

And then the tested forgings begin their trip to machine shop, assembly, and a lifetime of usefulness.

Photos by Van Fisher

The Oil-Struck, Scale-Struck Hammer Man.

MODEL 35 ACME

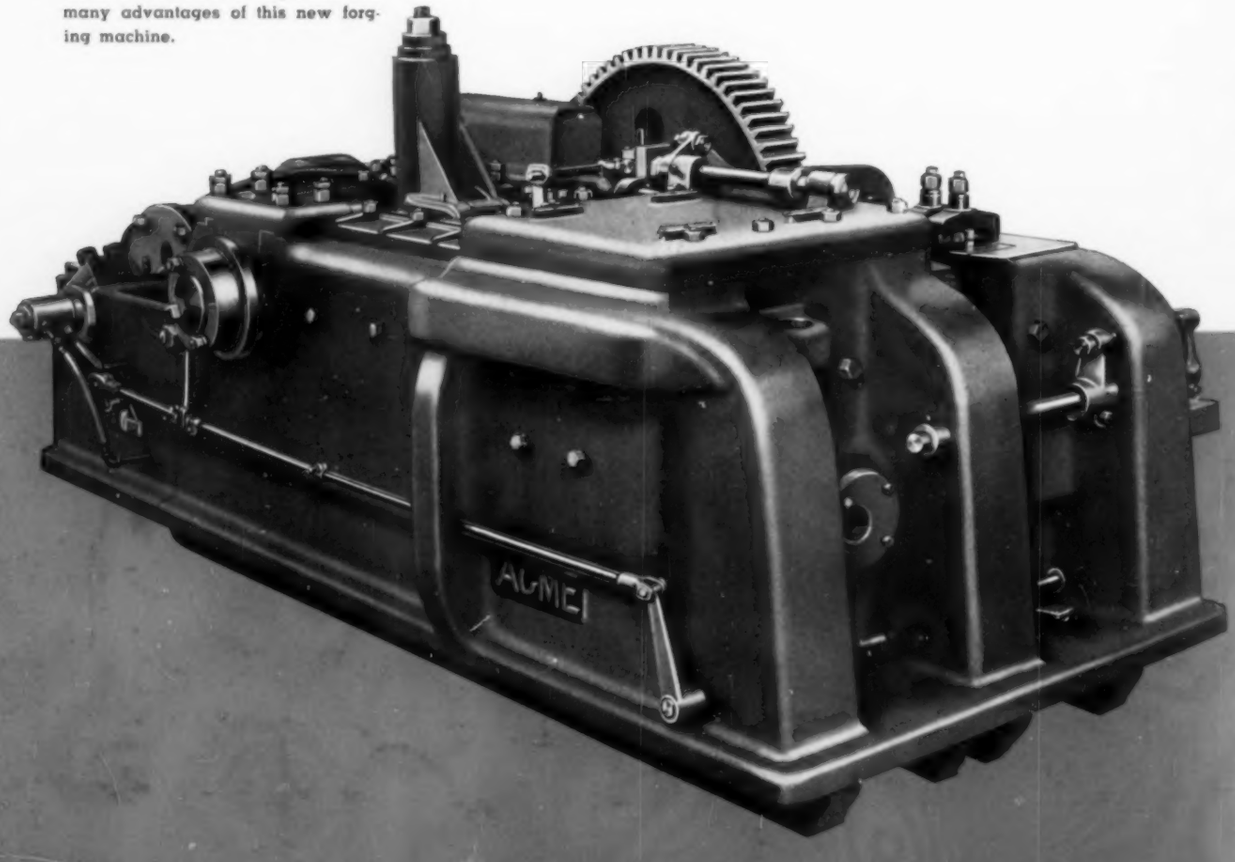
FORGING MACHINE

There are two outstanding developments in the design and construction of the Model 35 Forging Machine that have not only improved the operation of the machine but have resulted in better forgings.

First, the Cushioned Drive consisting of a multiple disc clutch cushions both starting and stopping action and eliminates shock to machine, parts and motor. This drive insures instant starting and provides a high factor of safety for the maximum work it may be called upon to handle.

Second, the latest achievement in modern forging machine construction has been developed by experienced Acme engineers — the Eccentric Header Slide. This unit eliminates the old Pitman movement and substitutes a more powerful, smoother action by means of the eccentric design. This design also permits location of heading tools above center line assuring accurate alignment of tools through complete cycle of stroke.

Complete design and construction details are fully covered in the bulletin illustrated. Acquaint yourself with these modern features of Acme Model 35 Forging Machines. Ask for a copy and see for yourself the many advantages of this new forging machine.



THE ACME MACHINERY CO.
CLEVELAND, OHIO, U.S.A.